Tropical, Subtropical Fruits And Flowers Cultivation

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Grape

SEED PROPAGATION

Germination

Effect of Temperature

The optimum germination of grape seeds in USA was obtained when held in moist peat moss at 5°C for 3-4½ months and then planted in a warm atmosphere. Scott and Ink in an experiment observed than freshly harvested grape seeds were poor in germination and such plants, if they did grow, were dwarf. They further reported that after-ripening of seeds in a moist condition at 40°F for 3 months improved germination. In another experiment, grape seeds stratified in moist sand at 2 to 6°C for 120 days germinated better than those stratified for 25 days, while soaking for 3 to 10 days gave a lower percentage and uneven germination. Seeds obtained from open-pollination usually showed a higher percentage of germination than those produced from self-pollination. In the tests over 4 seasons with Almeria grape seeds, the highest germination followed moist after-ripening treatment, either in storage at 33-40°F or by outdoor stratification. Drying the seed at 65-70°F after harvest and before stratification reduced germination slightly, while drying without subsequent stratification reduced it even more. Germination was much better in sand than in soil. A copper oxide seed dressing was beneficial only in the soil medium. With 6 cultivars after-ripening treatment for 12 weeks resulted in higher germination than did shorter periods of treatment.

Dolgova noted poor germination of grape seeds when stored in dry condition for 6 to 8 months, whereas storing the seeds in the berry or stratification in damp sand at 1° and 3°C for 180 to 210 days markedly improved germination and winter-hardiness of the seedlings. It was found that a greater percentage of viable seeds could be harvested from grafted plants which germinated with more vigorous shoot and root growth than seeds obtained from self-rooted parents.

Exposure to lower temperature between 0 and 10°C for 5 months was found effective in breaking the dormancy of grape seeds cv. Gewurztrarminer. The most effective temperature for breaking the apparent dormancy giving 40 per cent success was 0°C, and the effect was found to decrease progressively with the higher temperature.

Foriani and Coppola observed that storage at 4-5°C for 60 days raised the percentage of germination from 29.4 (fresh seed) to 42.2. The optimum temperature for germination of cold-stored seeds was 20°C and for fresh seeds 25°C.

Fanizza studied the interactions between cultivar and stratification, as also the germination temperature in grape seeds. He found a marked genotype environment interaction and noticed that a cultivar with high germination rate in one environment did not always show good results in another environment.

Costacurta *et al.* observed that germinability in cv. Tocai (early) was poor, and only long stratification improved it. Verduzzotrevigiano seeds appeared to have high degree of dormancy and responded more to stratification than the Merlot seeds which appeared to have broken dormancy by fruit ripening time and responded to warmer temperature more than Verduzzotrevigiano. When the seeds were kept in a peat, sand (1:1) mixture plus 0.3 per cent orthocide (Captan) in polythene bags at 0-2°C until the end of January the seeds showed 79.6 per cent germination 27°C.

Crescimanno *et al.*reported that transplanting in polythene bags under controlled conditions as well as in the field produced more than 80 per cent quality seedlings of Berlandieri Reseguier

n.I × Rupestris du Lot seeds. Seeds of grapevine cv. Romi Red germinated only after stratification (at 5°C and/or 18°C) and for normal seedling production a 60-day-stratification period was required. Warm stratification (18°C) for 50 or 60 days followed by cold stratification (5°C) for 30 days gave the best germination rate and the highest number of normal seedlings.

Seeds of cv. Patricia, fresh or dried (24 hr at 30°C), were stored in moisture-proof glass jars or in paper bags at 10°, 20° or 30° for 24 months. When stored in containers, fresh seeds remained viable at 10°, and dry seeds at 20°. In paper bags 20° was the worst storage temperature. Storage conditions had no effect on seed dormancy.

Effect of Growth Substances and Other Chemicals

GA_3 at 2,000 ppm replaced the dry storage period of seed in cv. Rosem-T-Lahore by one month and by 40 days in Bangalore Blue. According to Chadha and Randhawa, GA_3 stimulated and improved seed germination in all the 12 cultivars of grapes studied. Best results were obtained in almost all the cultivars when the seeds after-ripened for 45 days were treated with GA_3. In another experiment Randhawa and Pal found that fresh seeds of the vine cultivars Bhokri, Black Hamburg and Hussaini did not germinate during a 12-week period after sowing. The germination percentage gradually increased with the increase in the period of after-ripening. The best results were obtained with seeds after-ripened for 75 days. Pre-sowing treatment of seeds with GA_3, kinetin, thiourea, IAA and IBA did not affect the germination of fresh seeds but the germination of the after-ripened seeds of all 3 cultivars was improved by GA_3 and kinetin treatments. IAA was effective only on cv. Hussaini. The effect of GA_3 was more uniform and pronounced than that of kinetin. GA_3 at 500 ppm proved to be the best treatment for all cultivars with seeds after-ripened for 75 days, while in the case of kinetin 5 ppm was most effective. GA treatment was also found to be a partial substitute for after-ripening. Yeon-der *et al.* reported that cold requirement of grape seeds for germination can be replaced by 8,000 ppm k-salt of gibberellic acid. Anab-e-Shahi vines were sprayed up to 3 times, 20, 35 and 50 days after pruning, with 2,000 ppm SADH, 2,000 ppm CCC, 500 ppm Phosfon D, 500 ppm MH or 500 ppm TIBA. SADH application stimulated the subsequent germination of seeds from treated vines, whereas MH treatment reduced it. A single application of CCC stimulated germination but further applications reduced it. According to Kachru *et al.*, grape seeds kept in running water for six days germinated in muslin cloth itself. This was followed by 1,000 ppm GA_3 treatment before stratification for one month and then treated with 2,000 ppm of GA_3. All other chemicals such as kinetin, NAA and thiourea did not show any positive effect.

Manivel and Weaver reported 50, 12 and 80 per cent germination of dormant grape seeds by treating with GA_3 (5,000 ppm), morphactin (100 ppm) and ethepom (5,000 ppm), respectively for a period of 18 hours. However, the germination of scarified non-dormant seeds was found to increase by daminozide (5,000 ppm) treatment, while ABA, Chlormequat, benzothiazole-2-oxyacetic acid, ethyl alcohol and sulphuric acid reduced the germination. After-ripened seeds treated with GA_3 was found to promote germination, especially at lower concentration, i.e., 100, 250 or 500 ppm. The activity of GA_3 was gradual and regular in this regard, whereas GA_{4+7} and GA_{13} showed shift activity with a narrow concentration range for promoting germination. Stratification at 4°C for up to 120 days increased the percentage of germination of cv. Muscat Hamburg seeds and germination time was also reduced. Soaking seeds for 24 hr in 100, 1,000 or 2,000 ppm GA_3 increased the percentage germination of unstratified seeds, specially with 1,000 ppm. Treatment with similar concentration of CCC reduced germination of unstratified and stratified seeds, whereas NAA treatments, using similar concentration did not increase germination of unstratified seeds or those stratified for 30 days but increased germination was obtained with seeds stratified for 60 to 120 days, the increase was greatest at higher NAA concentration. GA_3 at concentrations up to 1,000 ppm did not influence the germination. Particular sowing time influenced, the germination of the seeds. When seeds of grape cv. Insolia, harvested in October, were sown

on different dates between January and August, the highest germination (45%) was found in February sowing. Pre-sowing seed treatment with IAA, IBA or ethepon failed to produce normal seedlings, but GA_3 at 5,000 ppm gave up to 29.4 per cent normal seedlings and kinetin at 20 ppm and thiourea at 2.5 per cent gave 4.8 and 3.7 per cent normal seedlings, respectively.

Pereira and Maeda observed that seeds of the cv. Patricia did not germinate in darkness or under constant temperatures in the range of 5° to 42°C. However, they germinated promptly just after harvest, in continuous light for 48 hr and alternating temperature of 35° and 15°C. Pre-treatment with GA_3 at 250-1,000 ppm increased germination from 28% in the control to 47-66.5%.

Influence of some alkaloids on the germination of grape seeds was studied by Kovalenko. In his experiment stratified and washed seeds of 4 grape cultivars were soaked for 48, 120 and 168 hours in aqueous solution of nicotinic acid, nicotine, caffeine, ephedrine, phenamine, an extract from tubers of *Colchicum speciosum* and cocaine at 20, 100 and 200 mg/l. The seeds were germinated at 16-22°C and the seedlings transplanted in pots containing chermozem soil. With the exception of nicotine all other treatments resulted in higher and more rapid germination than control.

Seed treatment with 0.05-2% cyanamide for 5 minutes proved an effective substitute for chilling of 4 *Viti. vinifera* cultivars.

Effect of Irradiation

Avramov and Jelenkovic reported that seeds irradiated with a cobalt source showed a germination response up to 10,000r and further higher dosages were lethal. Though the seedling survivability was positively correlated with germination, growth of the seedlings was retarded by irradiation with all doses except 1,000r for soaked seeds. Doses of 1,000-8,000r could not induce germination in the very light and undeveloped seeds of Himrod, but in cvs. Motia, Gulabi and Schuyler White the seed dormancy was broken and fresh seeds germinated. The highest increase in germination percentage due to irradiation was 42.5% in Motia seeds treated with 800r.

Biochemical Changes

When the seeds were stored moist at 5°C, after-ripening resulted in an increased amount of growth promoting substances similar to auxins in the seed extracts. The extracts of neither chilled nor non-chilled seeds showed the presence of gibberelin-like substances when tested on dwarf maize mutant plants. It was suggested that an increased syntheses of growth promoting substances occurred during stratification of dormant seeds and resumption of germination.

Zankov and Kolev studied the metabolic changes in the seeds of the scion cultivar Siroka Melniska and those of the rootstock Burisku × Rupestris 93-5 during stratification and germination. In Siroka Melniska stratification was associated with a relative increase in the amount of protein N and a reduction in the non-protein N and few amino acids, both in the embryo and endosperm. In the seeds of Burisku × Rupestris 93-5 during stratification and above all during germination vigorous hydrolysis of protein and polysaccharide reserves took place in the endosperm, accompanied by a rapid increase in non-protein N and simple sugars and their translocation to the embryo. Chohan and Dhillon recorded maximum germination when the seeds were stratified for 60 days. They observed that the activity of auxin within the seed increased with longer period of stratification and it was maximum in germinating seeds. Freshly extracted seeds did not show any gibberellin-like activity while abscisic acid-like inhibitors were found in the extract of fully ripe freshly extracted seeds. In studies with the grape cultivars R. kaciteli, Siroka Melniska and Chardomnay, Angelova and Lilov observed that the extent of seed dormancy was directly correlated with the ABA level, and the possibility of the presence of another inhibitor of phenolic nature was suggested to have a direct role on the dormancy of grape seeds.

Zankav and Angelova also reported that ABA content and germination rate, higher in seeds from the main shoots decreased and increased respectively during stratification. It was suggested that ABA content of germinating and germinated seeds are associated with ABA participation in general translocation and metabolism.

After the seeds (cv. Ugni blanc) were rehydrated and stratified at 2°C for 60 days, Broquedis found that β-D-glycopyranosyl abscisate (ABA-GE) content was nil or very low but some free abscisic acid (ABA) was present. ABA and ABA-GE levels recorded after 30 days confirmed the conversion of ABA-GE into free ABA, mainly during the first half of stratification.

The anatomical barrier seemed to obstruct the germination of grape seeds and the removal of outer layer was found to increase the germination percentage.

Germinability in very early, early and midseason table cultivars was 1.2-15.1, 3.5-28.0 and 14.5-48.0% respectively, whereas in nine cultivars it ranged from 62.5 to 87.0%. In table cultivars germination of seeds taken from grapes with 3-4 seeds/berry was appreciably better than germination of seeds taken from grapes with 1 seed/berry.

VEGETATIVE PROPAGATION

Cutting

Type of Shoot and Length of Cutting

Propagation by cutting selected from the middle of last season's canes and 10"-12" (26-31cm) in length was reported by Parson. Cuttings from Berlandieri vine with 2-year-old wood showed 86 to 99 per cent success, while those from the current season failed to produce roots. The degree of maturity of the current year's wood was found to play an important role in the propagation of vines as well as in setting of fruits, formation of shoots and development during the following year. In a preliminary experiment, using Chasselas de Fontainebleau, vigorous, well-rooted plants were produced from cuttings having only one bud. Markin reported that softwood cuttings of grape with an internode and two buds successfully rooted under mist in 10-20 days. Toskic and Avramov observed considerable variation in the percentage of rooting due to the length of the cuttings and climatological factors. Most satisfactory results were obtained with cuttings of 20-25 cm for Riparia portalis and Rupestris du Lot cultivars, while 30-45 cm cuttings proved better for Berlandieri × Riparia Teleki 8B, Berlandieri × Riparia Kober 5BB and Chasselas × Berlandieri 41B, and short cuttings were severely affected in dry weather.

Muscadine grape cuttings can be rooted quite readily by the constant mist method. Succulent, immature tip cuttings gave the highest percentage of rooting. Capria and Vega observed that cuttings, 1.2 m in length, taken in mid-winter, rooted better than the shorter ones, and were superior to those taken at leaf fall or in early spring. They further noted that cuttings of 40 cm length rooted much better when placed vertically in watered furrows and covered with soil than when placed obliquely in unwatered furrows. Penkov suggested to increase the length of rootstocks from the standard 32 cm to 40 cm as an antidrought measure in areas like northern Bulgaria where calcareous and typical chermozem soils prevail with poor water-holding capacity. In trials on the production of self-rooted vines, best results were obtained by planting cuttings of 60 cm length in furrows at a depth of $^{1}/_{3rd}$ of their length and covered with 4 to 6 cm thick soil. Trials conducted by Csepregi to increase vine rootstock production with 1 and 2 node cuttings of Berlandieri × Riparia Teleki 5C, showed that 2-node cuttings grew better in the nursery and were more adaptable to extreme environmental condition. The use of single node cutting was not considered suitable for large-scale production, but proved useful when the propagating material was in short supply. Investigations carried out at Palermo with 10 rootstock cultivars revealed that in respect of the number and quality of rooted cuttings, the mid and lower basal regions of the primary shoots showed better response than the upper basal cuttings, followed by lateral shoots from the basal and mid-regions. Rooting was also found to be influenced by the degree of ripening of the wood in the preceding season and was generally better in Rupestris types than in those derived from Riparia. The lower basal cuttings, with a thickened base, proved good material except in cv. 140 Ruggeri, in which they were often too large and hard. In another experiment with 779 and 1103 Paulsen and 140 Ruggeri basal cuttings (12 mm in diameter) gave the best rooting. In Riparia Gloire de Montpellier the basal cuttings were also

significantly the best for rooting. Basal, medial and apical cuttings were taken in February from pruning of 1-year-old rooted cuttings of the 2 vine rootstocks, 140 R (Berlandieri × Rupestris 140 Ruggeri) and 225 R (Berlandieri × Riparia 225 Ruggeri). Planting was carried out either at once or after 2 or 4 weeks', storage in damp sand. Compared with material from mature rootstocks the results were poorer in both quantity and quality. In 140 R, the medial portions rooted and the basal portions were the least satisfactory while in 225 R, the apical portions gave markedly poor results than the other parts and the medial region was only slightly superior to the base. The cuttings of 420 A and 5 BB, ranging from 10 to 100 cm in length were made. Good rooting percentages were obtained with lengths of 25-70 cm, the best root systems being those of 40 and 50 cm. Cuttings shoot development, particularly on 420 A, was closely correlated with root density. In an experiment with 10 vine cultivars, cuttings were taken from young, leafy shoots, with or without a small portion of old wood attached. These were planted in the open at 5-days intervals in May and 10-days intervals in June, in trenches contanining 50% soil, 25% sand and 25% compost. The rooting percentage was highest (60-80%) for cuttings with old wood attached, and with both types of cuttings rooting was better in the earlier plantings (Smakov, 1963). Cuttings with 3 nodes gave the best rooting response (90.73%), the corresponding values for cuttings with 4, 5, 2 and 1 node being 86.10, 83.33, 83.32 and 37.03%, respectively. Cuttings with 5 nodes produced the most leaves and roots and also the greatest number of long roots. Cuttings with 3 nodes required 70.8 days to shoot, while those with 1 node needed 97.2 days. Moti and Singh reported that softwood cuttings of Gulabi and Bhokri failed to root but the semi-hardwood cuttings of Gulabi gave 34% rooting. With hardwood of Gulabi and Bhokri the rooting percentage amounted to 75% and 80% respectively.

Alley observed that fruiting cultivars of grapes rooted better when the top bud of the cutting was left exposed that when it was covered with a mound of loose soil. In trials with the rootstocks cvs. Riparia × Rupestris 101-14, Riparia Gloire and Kober 5 BB, the percentage of rooted cuttings (50 cm stem section) taken at 5 points along the stem starting from the base, the number of roots/cutting and the development of scion cultivars grafted on to these rootstocks were determined. The results varied with each rootstock cultivar but generally the best results were obtained from cuttings taken from the middle and from each side of the middle of the shoot. In trials with the vine cv. Zhemchug Saba softwood cuttings taken during flowering from the middle part of the shoot gave 91.4-100% rooting. In the conditions of southern Ukraine, cuttings over 7.5 mm in diameter are not graded. Those of diameter 6.1 to 7.5 mm were considered suitable for grafting provided they contained not less than 12% carbohydrates and did not fall below 6 on the starch content scale.

In a trial with Rupestris du Lot, Berlandieri × Riparia Kober 5 BB and Chasselas × Berlandieri 41 B rootstocks, it was observed that root formation in all the three rootstocks was more active when the cut was made close to the node and Rupestris du Lot produced 28.5 per cent rooting when cut near the node and 6.0 per cent when cut through the internode.

Alley and Christensen observed no difference in the rooting percentage of the various types of cuttings; the largest roots were produced by mallet cutting, followed by the basal ones. Basal and field-run cutting performed best in terms of net gain in weight and they tended to produce the greatest number of usable rooted plants.

Weaver *et al.* observed that rooting of grapevine cuttings was usually the best in basal cuttings and poorest in apical cuttings regardless of collection date between 20th October and 9th February. In 2-year trials with 4 cultivars cuttings were taken from the basal, middle or apical parts of 1-year-old canes. In both years the mean rooting percentage was highest in basal (62-92%) and lowest (48-76%) in apical cuttings. Rooting was highest in Beauty Seedless followed by Delight and Perlette and lowest in Thompson Seedless.

The standard practice was to remove all but the top one or two buds before planting of cuttings of grapevine. An attempt was made for chemical disbudding by using NAA, and the variation in response was recorded in different rootstocks. Freedom and Ruby Cabernet were the most sensitive, Ganzin, St. George and French Colombard were less sensitive, while Harmony was the least sensitive.

Effect of Season and Temperature

Quinon studied the influence of the season of planting on rooting in grape cuttings and he concluded that in the coastal area of South Australia planting of cutting between May and July did not show any appreciable variation in the percentage of rooting. Planting in May produced the heaviest and strongest roots and abundant rainfall after planting was beneficial to root production. The most favourable temperature after setting out the cuttings appeared to be between 50 and 53°F in the soil at the base of the cuttings, and between 54 and 55°F in shade at 4 ft above the ground level.

Kostjuk suggested use of biological heating for stratification of the cuttings. The best result in his experiments was obtained when the cuttings were covered with a 20-25 cm deep layer of damp mixture of sawdust and horse manure with 35-40 cm deep layer of fresh horse manure placed over it. After about 4 days the temperature in the sawdust-manure mixture reached 24 to 25°C when the mixture was removed and the trench was covered with straw mats to maintain the temperature. An experiment with 1-year-old stem cuttings of 3 grape cultivars previously stored for 8 days at 3-4°C and kept in the dark in a saturated atmosphere for 2-18 days (to induce auxin blockage) showed increased root weight in 2 cultivars. Ribas and Conagin found that rootstock RipariaxRupestris 101-14 and Mourvedre × Rupestris 1202 rooted better during August, while Rupestris du Lot, Golia, Kober 5 BB and Aramon × Rupestris Ganzin No. 1 showed better rooting response in June. The optimum period for taking cuttings from rootstock cultivars was determined by a microscope study of cross-section stained with various reagents and by nursery observation. It was found to coincide with the period of maturity coming between the growing period and dormancy and characterized by high contents of starch and tannin substances. It occurred in

November-December and lasted from 2 to 6 weeks in the cultivars studied (Riparia Gloire, Craciunel 2 and 41 B), varying in length with cultivars and annual conditions. Leafy terminal or subterminal cuttings of 11 cultivars of muscadine vine were successfully rooted in sand under intermittent mist. With young growth taken early in the season the cuttings rooted in 4-5 weeks, but with cuttings from more mature shoots 6-7 weeks were required. With all the cultivars tested cuttings taken in July rooted better than those taken earlier or later in the season. Experiments were conducted on cuttings of the cultivars, Coarna Neagra, Muscat de Hamburg, Afuz-ali and Pearl de Csaba, maintained in either water or sand at 14° of 18°C, some being paraffined. Buds on cuttings kept in water at 14°C burst after 29-32 days and at 18°C after 15-18 days; those in sand averaged 20-23 days. The first roots appeared after 31-72 days depending on the medium, the cultivar and the treatment. The interval between bud burst and root growth diminished as the temperature was raised. Cuttings of Merlot vines were taken during the periods of dormancy, post-dormancy, pre-bud break, and bud break which lasted, respectively, from 15 August to 30 November, to 30 January, to 30 March and to 10 April. Treatment with IAA delayed bud break, but it did not greatly alter this general pattern. The total length of roots produced also differed in cuttings taken at different times, being high in those taken during dormancy, lowest in those taken immediately before bud break. Treatment with IAA always increased the total root length, but it did so most in cuttings taken just before bud break and much less in those taken during bud break. A pattern similar to the seasonal pattern of rooting behaviour was also obtained when the buds of cuttings taken in the dormant period were removed at successive 6-days interval after cutting, so that cuttings disbudded on the 12th day produced the least root, and those disbudded on the 24th day produced the most; the effect of IAA on this pattern resembled its effect on the seasonal pattern. In the rootstock cvs. Kober 5 BB and SO 4 the time of taking cuttings had little effect on rooting over bottom heat or in the nursery bed. In 140 Ruggeri, however, rooting was reduced in cuttings taken between December and February. Removal of buds from cuttings reduced rooting capacity in all

rootstocks. In a method used by the CSIRO at Melbourne, Australia, cuttings were taken in July and stored in damp sand until early August when they were put in plastic bags with sand and placed upright outdoors over a bottom temperature of 75°F. The vines grew well, reaching 5 ft or more in a season. The formation of roots at the base of fresh cuttings took 10-24 days at 29.5°C and longer at lower temperatures, but cutting date had no effect. Cuttings held in refrigeration required longer time for callusing, root formation and bud burst. IBA hastened the appearance of callus and roots but not bud burst.

In Australia, Scholefield obtained a height of 5 ft or more in a season when vine cuttings were taken in July, stored in sand and placed over a bottom temperature of 75°F and in mid or late September the vines were firmed in a wet soil in the field. Cuttings planted fresh (within 4 days of removal from the vines) appeared to root well, as well as cuttings stored in sand and planted in March and April. The cuttings stored in refrigeration longer than 2 months and planted late rooted less than cuttings stored in refrigerator for shorter periods Jujii and Nakano observed that bottom heat at 21°C was optimum for rooting of cuttings in early spring and warm air temperature further improved the root formation. They also noted that presence of growing buds on the cuttings also promoted rooting and their removal reduced it. Hardwood cuttings of cultivars Bhokri and Selection-7 gave the best results when planted in the first week of January rather than later. Rooting was found to improve by water soaking for 24 or 48 hours, and cuttings from the middle part of the cane rooted better than distal or proximal cuttings noted that canes of cv. 2-1, when collected in mid-May, cut into 15 cm length and treated with NAA alone or with IAA each at 1,000 ppm for 5 minutes, showed a greater percentage of rooting by hot water treatment. It was further observed that treatment of the basal part or the whole cuttings with water at 50°C for 30 minutes delayed root-initiation, while treatment of the apical part advanced bud-break and root initiation and increased the mean number and the total weight of roots. Minaeva found the best rooting by planting in spring at a soil temperature of 7-10°C to a depth of 40 cm.

Aurore grapevines (*vitis* sp.) propagated by softwood cuttings taken on 1 May, 15 May, 22 June and 20 July, 1981 were field planted the same year on 9 June, 25 June, 20 July and 12 August, respectively. Plants were harvested bare-root on 4 December, overwintered in cold (5°C) storage, planted in pots on 28 January and stored in an untreated greenhouse. Ten plants from each date were transferred to a greenhouse with 18°C minimum night temperature at 2-week intervals from 29 January to 12 March, 1982. Forced plants produced from cuttings planted in field in June flowered and produced attractive fruit cluster but July and August planted cuttings produced few or no inflorescence.

Cuttings, 25-30 cm long, of rootstock Kober 5 BB and scions Muskat Belyl (White Muscat) and Bastardo Magarachskil were subjected to various temperatures (40-62°C) for various lengths of time. The optimal treatment for regeneration was 10 minutes at 44-48°C. Kober 5 BB gave best callus formation, while Bastardo Magarachskil gave best shoot and root regenegation.

Effect of Water Treatment

The percentage of rooting was found to increase by soaking of cutting for 24 to 120 hours, 24 and 48 hours being best for Malbeck and 48 and 96 hours for Kober. After 4 months' stratification cuttings of the vine rootstocks 140 R and 1103 P were soaked for 24 or 72 hours in cold or tepid (30-55°C) water before planting. Active growth began first in those soaked in tepid water, irrespective of the duration of treatment, and last in the untreated controls, but 8 months later there was no difference in vigour. Rooting responses of 140 R were greatest to 24 hours in tepid water, whereas with 1103 P slightly better results were obtained with 72 than with 24 hours. The rooting and survival rates of Thompson Seedless cuttings and the average weight and number of roots per cutting were significantly improved by pre-soaking the cutting in water for 48 hours before planting. Soaking for 24 hours was almost as successful, but soaking for 72 hours had adverse effects. Soaking in hot (30°C) or cold (5°C) water reduced the rooting ability of fresh single node vine cuttings. The larger the soaking the greater was the reduction, and the use of

running water had a greater effect than. Immersing cuttings in water for 24 hours increased percentage rooting from 69.6 to 83 in rootstock 5 BB and from 18.0 to 38.3 in 140 R, shoot formation was also enhanced in 140 R. Rooting of 140 R was not affected by water in which 5 BB cuttings were soaked, but shoot development was inhibited. Root and shoot length in 5 BB were increased by treating with water in which 140 R cuttings were soaked.

Bautista and Vargas recorded similar percentage of rooting after 45 days (90-100%) in untreated control cuttings and cuttings immersed in water for up to 36 hr. A longer period of immersion (up to 96 hr) decreased percentage rooting and leaf and root development.

Effect of Growth Substances

Zimmerman used root forming substance on grape cuttings and reported that root formation was best induced on 4-6 nodes behind the growing tip. Kordes stated that treatment with IAA increased root formation in vine cuttings. When grafted, rootstocks were found to develop better and stronger roots after both stock and scion had been treated with this acid. Of the various concentrations of aqueous solutions, 0.05 per cent indolylacetic acid gave the best results in rooting in short time. The use of stimulant in grafting trials produced an increased root growth of the stock, but scion cultivars also formed roots at the point of union, Burgunder scion proved the only exception. When treated with IAA Riesling, Traminer and Silvaner cuttings showed a marked increase in rooting but Burgunder was less affected and Portugieser scarcely at all. If vine cuttings had an incision made into the rind before treatment with growth substances they produced roots in greater number and more rapidly than those not incised. Experiments with grafted cuttings by using IBA and IAA indicated that these substances had a definite appreciable effect on the vine, that of IAA being the greatest in the required direction. Vidal reported that 5 per cent solution of Hormodin proved effective in rooting of grape cuttings cv. Berlandieri La font No. 9, and obtained 70 per cent rooting, compared to 50 per cent in the untreated cuttings. Rives obtained better rooting performance including root growth in grape cultivar Riparia × Berlandieri hybrid 420A by using Hortomone at 2 teaspoonful/ 10 ml of water. A combined treatment with indolebutyric acid and KNO_3 greatly improved the rooting of cuttings of three cultivars of vine rootstocks obtained from field material. Harmon found marked variation in rooting of cuttings in different cultivars due to the treatment with growth substances. Where results were favourable, immersion of the basal ends of the cuttings for 24 hours in concentrations of 0.005 to .02 per cent IAA gave fairly good rooting. Cuttings with a node at the base formed rather better condition for rooting than internodal cuttings. A 0.0025 per cent aqueous solution of IAA stimulated root-growth of cuttings. Experiments with cutting of cultivar Riesling × Sylvaner possessing one bud showed that heteroauxin and a proprietary hormone preparation Roche 202 increased root formation, but suppressed shoot growth as the concentration was increased. A suitable hormone concentration, however, applied for the right length of time was found to promote root formation markedly, while it also enhanced shoot growth.

Green wood cuttings were treated with 0.01 per cent heteroauxin. After 7-10 days, swellings appeared on the lower end of the treated cuttings while no swelling appeared on untreated controls. Later, 15-16 days after planting numerous roots developed from the swelling. In the untreated cuttings root emerged later and the number of roots were much fewer. Immersion for 4, 24 or 48 hours of Berlandieri × Riparia 420A and Riparia × Rupestris 101-14 cuttings in cow urine at strengths of 1 urine, 2 water, 1:1 and 2:1 resulted in better root formation. In the cultivar Berlandieri, cuttings treated with 5 ppm IBA for 138 hours produced 100% rooting. The difficult-to-root grape cv. Berlandieri showed higher percentage of rooting and root number per cutting when treated with IAA at 333 and 150 mg/l, the effect of IBA was, however, detrimental. Flerov and Kovalenko. observed better rooting when cuttings were treated with naphthaleneacetic acid and nicotinic acid at 100 ppm for 48 hours. Martinez did not find any beneficial effect of indoleacetic acid and naphthaleneacetic acid on rooting of 41B de Millardet cutting.

He, however, observed good rooting when the cuttings were superficially wounded at the base and immersed in water before planting. Ortho-chlorophenoxyacetic acid and naphthoxyacetic acid increased the percentage of rooting, produced better root system and subsequent development of cuttings of Solonis × Rupertris 216-3, Chasselas × Berlandieri 41B and Rupestris du Lot. Ballatore reported that Rupestris and Berlandieri hybrids, in general, rooted more favourably than Riparia and its hybrids when the cuttings were treated with Seradix B_1 or Rootone. In another experiment on difficult-to-root cv. 41B de Millardet, cutting was treated with indoleacetic acid at 15, 25 and 50 mg/l for 6 and 12 hours, the lowest concentration (15 ml/l) and shorter dip showed 38.4 per cent rooting, compared to 31.4 per cent in control. While cv. 110 Richter showed better rooting when treated with 25 mg/l naphthaleneacetic acid for 12 hours.

In a trial at Zemunu in 1947-50 with 4 synthetic hormones, Rootone and Roche 202 showed better rooting of difficult-to-root Chasselas × Berlandieri 41B. Crescimanno reported that treatment with vitamin B_1 in distilled water considerably increased rooting of grape cuttings and distilled water alone had also a positive effect, but Seradix 1, 2 and 3 had no beneficial effect on rooting. It was found that NAA at 40 ppm produced heigher percentage of marketable cuttings, and immersion of the root system of 1-year-old plants in a solution of vitamin B_1 at 10 ppm for 13 or 20 days resulted in a heigher ratio of well-rooted plants, i.e., 58 per cent (13 days) and 61 per cent (20 days) as against 31 per cent in control. With cuttings of Couderc 161-49 of 7-8 mm in diameter and 70 cm in length, which were moistened and dipped in dry 'Rootone Sem', no significant increase in the percentage of rooting of the treated cuttings over control was noted, but shoot and root growth was accelerated due to the treatment. Similarly, neither IAA at 25 or 50 ppm nor urine of cows in 15 per cent aqueous solution was found to improve the rooting of grapes cv. Paulsen-1103, while Rodriguez Lopez noted excellent rooting of grape cultivars 41B, 99-R and 161-49 when treated with naphthaleneacetic acid at 150 ppm followed by planting in fine sand under glass at 85 to 90% relative humidity and 17°C temperature. Satisfactory rooting was observed when the apical end of softwood cuttings was soaked for 15 hours in heteroauxin at 200 mg/l.

May reported that maleic hydrazide inhibited rooting in cuttings of grape cv. Sultana even at a low concentration of 3 ppm.

Treatment with GA_3, IBA and NAA did not improve the rooting of St. George, 1613 or A × R No. 1 rootstocks, while in cv. Salt Creek, IBA treatment was beneficial, mixture of IBA+NAA was detrimental to the rooting of 1613, Salt Creek and AxR No. 1. Although neither IBA nor NAA had any significant effect on the percentage of rooted cuttings produced, the former increased the number of roots per cutting. The length of time the cuttings were kept in sand beds, however, influenced the rooting percentage and the number and length of the roots, a 10-week period being more favourable than 6 or 8 weeks. In Experiments with cuttings of Malbeck and Kober 5 BB (easy and difficult-to-root cultivars respectively) treatment of the cuttings with IBA at 50 ppm plus biotin at 1µg/1 resulted in a greater production of roots than treatment with either material alone. The stimulation produced by the IBA+biotin treatment was greater than that caused by IBA+autolysed yeast extract. When no growth substance was applied cuttings of *Vitis berlandieri* formed abundant callus both at the apex and at the base, but formed no roots. Basal application of IAA induced abundant root formation at the base of the cuttings. Cuttings of 7 vine cultivars treated with 0.02% IAA, 0.01% IBA or 0.005% NAA for 18-24 hours rooted better than the controls. The addition of 0.2% ascorbic acid to the growth substances did not cause any further improvement in rooting. The treated cuttings started to root before bud burst, whereas the controls showed shoot growth before root development. IBA and to a lesser extent, IAA were more effective in promoting both root and top growth than was NAA.

Antognozzi *et al.* reported that cuttings of rootstock of two types of vine when grafted with Sagrantino scions and treated with IBA at 8,000 ppm showed significant increase in rooting and root number per cutting under bottom heat. The percentage of

rooted cuttings was, however, reduced with Captan at 0.2 per cent. Two clones of Berlandieri Reseguier No. 1, and 2 or 4 clones from each of 7 Berlandieri crosses were treated with 300 or 500 ppm solutions of CCC at 7-8 day intervals to shorten the internodes as they were produced. Cuttings consisting of the 4 lowest nodes of main, lateral or sub-lateral shoots were cut, bundled and placed in rooting trenches. Rooting was rather poor in the Berlandieri clones and Chasselas × Berlandieri 41B clones, but was considerably increased by CCC treatment, whereas the effects of CCC on the other more readily rooting six hybrids were negligible or negative. In no case were roots produced on cuttings taken from sub-lateral shoots.

Singh *et al.* also reported that treatment with IBA at 500 ppm promoted rooting in hardwood cuttings of cv. Perlette. Antognozzi and Preziosi recorded 75 to 85 per cent rooting in cuttings of cv. Kober 5 BB and 60 to 80 per cent in cv. 420A by using 1,000 or 4,000 ppm of IBA with or without waxing. Cuttings of vine cultivars Kara-Shaany and Ag-Shaany were kept for 12 hours in a solution of 0.0025 per cent heteroauxin, 0.005 per cent NRV, 0.0012 per cent boric acid, 0.01 per cent superphosphate, 10.0 per cent animal urine or 20.0 per cent fresh cowdung with or without heteroauxin; NRV or a 0.05 per cent mixture of micronutrients caused good rooting, and growth was stimulated after treatment with animal urine, heteroauxin, NRV and micronutrients. Singh and Singh observed that the rooting performance of hardwood cuttings of Thompson Seedless and Himrod grapevines was not improved by storing the cuttings in wet sand for a month before planting. The application of 500 ppm IBA had a stimulating effect on rooting, while higher concentration of IBA was found to be detrimental. Peterson reported that Dogridge grapevine cuttings treated with 0.2 per cent IBA rooted well in a sand bed over bottom heat arrangements. Cuttings were taken from Merlot grapevines on 27 March just before bud-burst, the buds were removed and then placed the right or wrong way up in water or in 40 ppm IAA solution for 24 hours. They were then placed with untreated control, the right and wrong way up in water or sawdust or horizontally in sawdust. Root formation in the untreated control was negligible, but water treatment improved it somewhat and IAA treatment promoted in considerably. Rooting was also much better in the sawdust than in water, showing the importance of O_2 availability.

Basal and subterminal hardwood (winter) cuttings from 1-year-old canes of *Vitis labrusca* cv. Improved Isabella rooted well in sand (65.2-69.0 per cent rooting) and in a medium made up of equal parts of sand and top soil (63.0-82.2 per cent rooting). In a second experiment, percentage of rooting was greater in cuttings from 3-year-old canes (87.0 per cent) than from 1 or 2-year-old canes (31.5 and 78.0 per cent respectively). Basal and subterminal cuttings from 4-year-old canes of cv. Semillon were dipped for 24 hours in 25-1,000 ppm IBA or IAA, alone or in combination. The percentage rooting was highest in basal cuttings treated with 50 ppm IBA reported that treatment with IAA at 0.01 per cent stimulated root formation in cuttings of White Muscat, Agadai and Rkaciteli. A significant increase in the production of standard transplants was noted in White Muscat with IAA treatment. In an experiment with hardwood cutting of cvs. Rumi Red, Rumi White, Rumi Black, Thompson Seedless, Rozaki and Kazzaz, Habib *et al.* observed that the cuttings after treating with IBA for 24 hours showed differential responses in rooting. The survival rate was found to be positively correlated with the initial carbohydrate content of the cuttings and negatively correlated with the initial nitrogen content. Treatment of cuttings with IBA increased rooting significantly to 85-98 per cent in all the cultivars. Radzhabov reported that application of CCC to the mother plant had a beneficial effect on rooting, development of aerial parts of rooted cuttings and subsequent development of the plant.

Chapman and Hussey recorded 100 per cent rooting of Dogridge bench graft (scion cv. Shiraz) by treating the cuttings with IBA and NAA at 200 ppm for 24 hours, while in Ramsey the percentage of rooting was 76. Chapman and Hussey reported that treatments such as (i) 24 hours soak in 200 ppm IBA+NAA, (ii) 24 hours soak in 200 ppm IBA, (iii) 5 seconds dip in 2,000 ppm IBA, (iv) dip in Seradix No. 2 dry powder and (v) untreated control showed 76, 71, 73, 61 and 31 per cent rooting, respectively in hardwood cuttings of cv. Ramsey, of which treatment with 2,000 ppm IBA as dip for 5 seconds was the most economical and practical too. Treatment with SADH and CCC during the dormant period in late February was found to influence rooting, CCC increased the fresh weight of the roots but did not affect the time of rooting, while SADH increased the time of root initiation. Ehrlinger and Howell reported increased rooting of 15 grapevine cultivars by treatment with 3,000 ppm IBA and propagated in sand with bench heating at 23-24°C and intermittent misting for 6 weeks. Eris and Celik also observed that treatment with GA_3 at 50 to 400 ppm and with SADH at 1,000 and 2,000 ppm inhibited the root formation, while CEPA at 100 to 800 ppm delayed the root formation and reduced fresh weight. Treatment with CCC had no effect on rooting, but at 2,000 ppm the fresh weight of root was increased. Dormant cuttings of muscadine grapevine cultivars Hunt and Cowart, rooted best early in the dormant season, although root quality was poor and the percentage of rooting was rather low. Large diameter cuttings rooted better than small diameter ones. Medium bottom heat was necessary for root formation. No significant rooting response was observed with IBA, Ethephon, precallusing or sucrose treatments, or with mallet (heel) cuttings. The apical end of grapevine rootstock cuttings of cultivars Schwartzman and Craciunel was treated with NAA, kinetin or mixture of the two compounds. High rates of kinetin (25 and 50 mg/l) and low rates of NAA (1 and 10 mg/l) promoted callus development at the apex. This was overcome by dipping the base of the cuttings in a mixture of 0.35 g IBA in 200 ml 96% ethanol + 0.5 g nicotinic acid in 600 ml water.

The effects of 120×10^{-4} M IBA and 3 to 12×10^{-4} M chlorogenic acid (CA) and their mixtures on cuttings of 4 rootstocks were studied by Moretti and Borgo, Kober 5BB responded well to 12×10^{-4} M CA and to IBA+3×10^{-6} M CA. The best response by 1103 P was to IBA+3×10^{-6}M CA. The best natural rooting was observed in 110 R, and treatment with IBA+CA had a negative effect on root number. *Vitis berlandieri* R 2 showed fairly good natural rooting but IBA improved this as did 6 and 12×10^{-6} M CA and IBA+3×10^{-6}M CA to similar extents.

Single-node cuttings of three Berlandieri × Riparia hybrids (420A, 225 Ru, and Kober 5BB), three Berlandieri × Rupestris hybrids (140 Ru, 1045 P and 17.37), and Chasselas × Berlandieri 41B were prepared in December, stratified in sand at 10°C till March and then dipped in 0, 500, 1,000, 1,500 or 2,000 ppm IBA with or without paraffin wax application to the distal end. The cuttings were examined after a further 45 days in Hoagland solution at 23-25 °C. Natural rooting was highest in K 5BB (47.8%) but under 30% in the other rootstocks. It was increased by waxing (especially in the poorest rooter, 41B) but IBA treatment was more effective, the increase being proportional to the concentration. Waxing plus IBA treatment had the greatest effect. In another trial, percentage rooting with 2,000 ppm IBA plus waxing ranged from about 45 in 420A to about 75 in K 5BB and was near 50 in 41B

Application of IBA or NAA at 25, 50 or 100 ppm in hardwood cuttings of several rootstock varieties, stored at 5°C for 50 or 86 days, enhanced rooting.

In an experiment on 140 Ruggeri, a difficult-to-root stock, CCC and GA_3 were treated 3 times and the rooting ability of cutting was measured. Chlormequat reduced shoot growth and enhanced lateral development compared with untreated controls, but GA_3 retarded the growth of laterals. The quantity of wood suitable for propagation was, however, similar for treated and control plants. Chlormequat treatment of stock plants markedly improved rooting in cuttings which were dipped (basally soaked) or not dipped in water for 24 hr. Rooting was unaffected by GA_3 treatment of stock plants. Dipping in water itself improved rooting compared with no dipping.

Grafts of cv. Chasselas on Riparia × Rupestris 101-14 rootstocks were held (3-5 cm deep) in 0.01% IAA solution for 24 hr or dipped in 0.1 or 0.2% IAA for 1-1.5 seconds. All treatments improved rooting except in grafts which already had roots. It is suggested that grafts with roots should not be treated before planting.

In one greenhouse experiment, woody cuttings of 5 rootstock cultivars were treated with 5 concentrations of IBA and rooted under intermittent mist. Untreated control cuttings of Kober 5BB, Rupestris du Lot, 420A, R-99 and 101.14 cuttings gave 67.5, 75.0, 20.0, 55.0 and 85.0% rooting, respectively and these percentages declined in treatment with IBA (1,000-4,000 ppm). In another greenhouse experimdent with softwood cuttings of 6 rootstock cultivars, IBA was applied at 2,500 ppm. In most cases the untreated cuttings rooted better. In a 3rd (field) experiment with 5 cultivars, the cuttings were treated with 5 IBA concentrations. Rooting was best with IBA treatments.

Pre-planting treatment of rootstock cuttings stimulated root formation and improved rooting and plant survival in the nursery. Production of grafted transplants in the nursery was increased by 3.4-15.7%, depending on the diameter of the cuttings. The optimum application rate for heteroauxin was 0.1%.

In an experiment on rooting in cuttings of Kuggeri 140, Bartoloni and Fabbri stated that natural adventitious root formation was low or nil in November-December. Spraying with 1,000 ppm CEPA had no beneficial effect on natural adventitious root formation and autumn application had negetative effect on rooting. IBA treatment stimulated root development during natural rooting, cold storage markedly enhanced the bud sprouting of the cuttings.

Mist and Media

The mist propagation method of hardwood cuttings from shoots at the normal pruning time and planting out the rooted cuttings 3-4 months later proved very useful. This gave a first crop of about 1 ton per acre in the second season. A further advantage of this method is the uniformity in growth and the low failure rate of 1% in the field or 5% during the whole propagation period including the 2 seasons in the field. By selecting suitable cuttings and rooting them under mist in a heated bed, small plants suitable for experimental purpose, were obtained which gave ripe fruit bunches 2 months earlier than was possible from vines in the field. Under Australian conditions, cuttings taken towards the end of December gave the best results.

Cuttings of the vine cultivars Frankenthal and Foster planted in sand (particle size 0.5-1.0 mm) showed 50 and 43% rooting, respectively, and those in a clay ksubstrate showed 81.5% and 76.3% rooting respectively. Softwood cuttings of 4 vines cultivars treated with heteroauxin were raised in the following substrates, pit, river and seaside sand and a 1:1 mixture of hotbed soil and seaside sand. The highest percentage rooting and the maximum root development were obtained in seaside sand. Berlandieri R1, notably difficult to propagate from hardwood cuttings, showed 100% rooting from both softwood (apical) and semi-woody cuttings in quartz and under intermittent mist with bottom heat at 30°C. Among the 5 other rootstocks tested the lowest rooting percentage (75.6 for apical and 89.6 for semi-woody cuttings) were recorded in 140 R. Two-node vine cuttings were soaked in 0.25% humic acid for 24 hours and set in 3 different substrates. The weight of the roots produced in perlite was 8 times that produced in hot-bed soil whereas the weight of shoots was only double. Rooting in sand was better than in hot-bed soil but much poorer than in perlite. Cuttings were taken continuously from potted plants grown by standing them in a nutrient solution in the greenhouse and rooted in mist chamber. Percentage take of cuttings was more than 95% in vermiculite, coarse sand or a peat/sand mixture and the time taken varied from 9 to 22 days for rooted cuttings to begin new growth when transferred to peat pots. Constantinescu reported that treatment of vine cuttings with paraffin, followed by propagation in water culture gave better results than by using sawdust, moss or sand as rooting media.

Other Treatments Influencing Root Formation

In an experiment at Bologna University in 1940 and 1941 with grafted cuttings of Paradisa or 420A, spraying with a 25% emulsion of paraffin oil at the time of planting resulted in 59 per cent rooting, compared to 38 per cent in the control. Staurakas and Vlahos reported improvement in rooting by removal of buds and dipping in paraffin wax.

Adventitious root production on vine cuttings was promoted by human chorionic gonadotropin (HCG). Antiserum to HCG depressed rooting, and its effects were attributed to the antibody component since rooting in normal serum was much higher. The treatment of vine cuttings, before planting, with a water suspention of phosphorobacterin or azotobacterin increased the number of thick roots (diameter 1-3 mm) and the length of the main root, and reduced the number of fine roots (diameter less than 1 mm) compared with untreated controls. Shoot growth was also more vigorous on the treated cuttings.

Two-bud cuttings of Berlandieri × Riparia T 5C and Berlandieri × Riparia SO_4 were rooted in a 1 : 1 sand : perlite substrate using a nutrient solution containing 0 to 1,000 mg/litre K_2SO_4. Increasing K_2SO_4 content of the nutrient solution proportionately increased the K content of the shoots and especially of the leaves, and simultaneously reduced callusing. A close negative correlation was found between leaf K content and shoot callusing.

Polyak *et al.* also observed decreased callus formation at apical ends of two-bud cuttings with increased NPK concentrations, especially K, in the nutrient solution. SO_4 cuttings were more susceptible than T 5C cuttings. With increasing K content in canes and leaves Ca and Mg contents decreased. Maximum carbohydrate contents and satisfactory callus formation were obtained with cane K values of 0.3-0.5% in both rootstocks.

In laboratory trials, cuttings of the rootstock cv. ChasselasxBerlandieri 41B were treated with the 3 chelates each at 0.05, 0.075 or 0.10% and then rooted in sand. Treatment with 0.05% Fe-chelate gave the best rooting (100%) followed by 0.05% and 0.075% Zn-chelate. The effective treatments also improved the growth of the rooted plants in pots. Cuttings from rootstock Berlandieri × Rupestris 140 Ruggeri were held for 24 hours in water solutions of Vitamin A, B_1, B_2, B_6, at 125-2,500 ppm, B_{12} at 5-250 or C at 15 to 2,500 ppm. Vitamin A, B_2, B_{12} and C had an indifferent or negative effect on root formation and no effect on growth compared to water treated controls. Vitamin B_1, and B_6, however, although had an inhibiting action on root formation, enhanced cutting growth, leading to average cutting weight of 44-45 g compared to 37 g for the controls.

In field trials at 2 sites in Italy, the foliage was sprayed (or not) in late July and again in August with 50+50 or 100+100 ml Ergostim (folcysteine+folic acid) in 10 litres of water, where Ergostim was applied the rate of applied N was halved (from 80 to 40 kg/ha). The cuttings were variously composed of each of 8 cultivars and 3 rootstocks. On an average, high Ergostim + low N treatment improved the production of rooted cuttings by 3% and reduced cost by L 1.7 per cutting planted.

Treatment of the basal 10 cm of 50 cm long cuttings of the vine *(Vitis amurensis)* in high tension electric fields greatly improved rooting and the best result was obtained by exposure to 4 kV/cm for 5 seconds.

In an experiment, 40-45 em long cuttings were placed in sawdust and charged with 2 carbon electrode currents of 500, 800 and 1,100 volts for 10, 20 and 30 minutes in every 24 hours for 12 days. All the treatments showed much earlier bud-break than in the untreated controls, but with 500 and 800 V bud-break was earlier, while the cuttings rooted or developed callus earlier by treatment with 1,100 volts. Pupko reported that electromagnetic treatment appreciably improved rooting and the optimum time of treatment was 30 minutes in two cultivars of grape.

Cuttings from plants of Kober 5BB given long day treatments showed and increased production of roots and callus on leafy cuttings but a decrease in rooting and callusing on defoliated cuttings. Cutting from plants grown in 12-hour day showed increased callusing and rooting on defoliated cuttings and decreased callusing and rooting on leafy cuttings. Kudryavkin also reported that the photoperiodic condition of the mother plant had considerable influence on the rooting of vine cuttings. Cuttings of *Vitis amurensis* rooted best when taken from plants grown under natural day and the cuttings of cvs. Khusain and Severnyi showed better root formation from plants grown under 14-hour light (long day). Cuttings grown in total darkness, or in darkness for 10-40 days after planting showed reduced root growth which then increased with increasing exposure to light.

Portjanko suggested a new method of stratifying cuttings known as Kiljcevarie. In this method the cuttings were placed

vertically with their morphological upper ends on a layer of ice and snow, while the morphological basal ends were covered with a layer of soil. This method showed marked success in the rooting of grapes. Bisson noted that during stratification, wood which has lost more than 7 per cent of its moisture content showed loss of vitality, and soaking the cuttings before planting was useful even for carefully stored wood, provided it has not lost more than 10 to 12 per cent of its moisture content.

Luini studied the influence of polarity on rooting. Cuttings were taken from Merlot grape vines on 27 March just before bud-burst; the buds were removed and they were trimmed to 6 cm and placed the right or wrong way up in water or 40 ppm IAA for 24 hours. Root formation in the untreated control was negligible but water treatment improved it somewhat and IAA treatment promoted it considerably. Rooting was also much better in the sawdust than in water, showing the importance of O_2 availability. Least rooting occurred in cuttings held horizontally and most in those held up side down. Most roots were usually formed at the bottom of the cutting, fewer arose at the bud end and fewest in the middle, but the apical applications of IAA reversed this trend causing most roots to arise along the cutting or at the apical end.

Kucher and Zherebin reported that enomelanins are melanin pigments of cultivated grapevine affecting the endogenous regulation of redox processes, homeostatic hormone reactions and other physiological processes. In nursery trials enomelanins stimulated root formation in Riparia × Rupestris 101-14 rootstocks but had no effect on BerlandierixRiparia CO-4.

Cosmo and Pieri carried out experiments for 3 consecutive years with 1 per cent Boardeaux muxture, 0.3 per cent Captan and 0.3 per cent Zineb, which were sprayed on the mother plants; cuttings were taken in the following spring, left for 6½ weeks and then planted in pots. Each group contained 8 bench graft and 10 ordinary cuttings. Treatment with Bordeaux mixture showed feeble rooting in 7 grafted and 6 ordinary cuttings, Captan-treated plants showed only 50 per cent rooting, while stronger and more numerous roots with distinctly greater shoot growth was found in 6 grafted and 7 ordinary cuttings of the Zineb-treated plants.

In single-bud cuttings of cv. Kyoho, treatment with Thidiazuron in November enhanced callus formation. The percentage of callus growth increased linearly with the increase in Thidiazuron concentration from 6 days after treatment and reached a plateau at 12 days after treatment. Maximum callus formation was induced by 100 µM concentration. In a parallel experiment the effect of Thidiazuron on bud-break was compared with that of 1% cyanamide. After 16 days, 76.5% of cyanamide-treated buds had broken, compared with a maximum of 29.4% of those treated with Thidiazuron at 100 µM.

A marked difference was found to exist in the rooting ability of the cuttings of different groups and between the members of the same group of hybrids. Even cuttings from one and the same vine showed differences in performance . In a comparative study with 6 cultivars of grape cuttings, Ozkaban and Konarli recorded 29.3, 63.1, 6.6, 22.0, 64.6 and 44 per cent rooting, in Paulsen-1045, Paulsen-1103, 161-49C, 41B, 5BB and 420A cultivars, respectively.

Barabal'chuk and Klimenko reported that immersing the basal end of cvs. Aleatiko and Kober 5BB cuttings in 2-4% solution of H_2O_2 for 24-48 hours stimulated rooting.

Gendiah reported that inoculation of the rooting medium of 1-year-old Banati cuttings with endomycorrihizal fungi, *Glomus mosseae* resulted in increase of 70, 121, 90 and 85 per cent for the number of roots, root length, root and top dry weight, respectively, compared with 2-year-old non-inoculated cuttings. Inoculation with *G. mosseae* caused an increase in root and vegetative growth for cuttings of different diameter, with cuttings of 8-9 mm diameter giving best growth, comparable with 2-year-old non-inoculated cuttings.

Storage of Cutting

Experiments on the storage of vine cuttings showed that conservation of nutrient reserves was better in long and thick cuttings than in short and slender cuttings, and that the storage

temperature should be below 10°C. The storage atmosphere should be kept as near as possible to the composition of ordinary air.

Cuttings of the vine cultivars Anab-e-Shahi and Selection 94 were packed moist sawdust for 10 days and were then planted out. Anab-e-Shahi did not callus either before or after planting and the rooting percentage was 65. Selection 94 callus was formed on 72% of the cuttings before planting and the rooting percentage was 62%. It was recommended that cuttings of cultivars that normally form callus should be planted only after they had formed callus.

Grape vine stem cuttings (cvs. Perlette, Pearl of Csaba and Convent Large white were dipped in wax and/or packed in moss or sawdust before being wrapped in alkathene paper and stored for 40 days. Subsequent mean sprouting 69.4% in cuttings which had been packed in moss was equal to that of untreated cuttings planted immediately after pruning or after storage in alkathene paper for 40 days.

Vine cuttings, 40-45 cm long and 7-8 mm in diameter were taken in November, treated with a fungicide and stored under a polythene cover. After storage they were found better developed and gave up to 5% more transplants than controls stored in the conventional manner in sand.

The effect of soaking of propagation material (stock and scion) in water or Chinosol before and after storage was tested in several cultivars. It stored best when first soaked in a 0.3-0.5% Chinosol solution, then sealed in plastic bags and held for 3 months at 1°C. It was finally given a second treatment of 5-hour soaking in water or 0.3% Chinosol.

Biochemical Changes During Root Formation

Oinoue suggested that there was a morphological limit in the cutting outside which reserve foods were no longer available for the formation of new shoots and roots.

Changes in metabolic activity during the regeneration of root in cuttings of 41B Chasseles × Berlandieri and 1202

MourvedrexRupestris were studied by Klein. No correlation could be found between the root forming capacity and sugar and starch content, but in both the cultivars the root forming capacity of cuttings taken from the basal and middle parts of clones showed increased correlation with osmotic values.

The influence of the nutrition of the mother vine on the rooting of cutting was studied by Samish and Spiegel Roy. The results revealed that nitrogen fertilization reduced the weight of root per unit length of canes, but had no apparent effect on rooting or root quality. Complete NPK fertilization increased the starch content and the rooting percentage and also improved the quality of the young plants. Application of zinc showed an increase in tryptophan content. It was found that increased auxin production from accumulated tryptophan caused the beneficial effects of these treatments. Lustince found that vine cuttings after a quick-dip treatment with IBA showed increased phosphatase activity and decreased catalase activity until the appearance of the callus and the first roots. Enzyme activity was determined over a wide range of temperatures.

Lilov found that at the beginning of stratification the free form of bios, a vitamin complex, accumulated and reached the maximum which subsequently declined. The extent of the increase and decrease was greater in cuttings treated with growth substances than the untreated ones.

Tizio and others from the results of the experiments on cuttings of Rupestris du Lot and Malbeck (good rooters) and Kober 5BB (a shy rooter), concluded the following : (i) Immediately after the cuttings were taken there was no endogenous auxin activity but some activity was observed after stratification, especially in Malbeck. (ii) The cultivars that rooted easily showed a greater capacity to mobilize carbohydrate reserves during stratification and a higher catalase activity after stratification, (iii) In the easy rooting cultivars, the osmotic pressure was higher before stratification than in the shy rooter, and fell more sharply during stratification to the same final level, (iv) No interaction between auxin activity and nitrogenous cofactors was observed which could explain the differences in rooting capacity, (v) The

rooting capacity in the same 3 cultivars was greatly improved by immersing the bases of recently stratified cuttings in running water for 48 hours. The percentages of cuttings which rooted after 24 hours' immersion were 26 for Rupestris du Lot, 52 for Malbeck and 74 for Kober 5BB. After 48 hours' immersion the percentages were 83, 100 and 93 respectively, suggesting that rooting inhibitors had been removed. After 100 hours' immersion the percentages were 51, 45 and 98 respectively, suggesting that in Rupestris and Malbeck but not in Kober, growth factors had also been removed. (vi) In rooting and shoot growth, cutting of Malbeck and Kober responded positively to 2.5 ppm of 2, 4-D. the response was reduced when 8% sucrose was added. At 5 and 10 ppm both 2, 4-D and 2, 4, 5-T had an inhibiting effect, especially on shoot growth. Root production was much greater with 25 ppm NAA alone than with a mixture of this with 5 ppm 2, 4-D and 100 ppm IAA. The addition of sucrose to the mixture further reduced the effect. The shoot inhibiting effect of 2, 4-D was not counteracted by the presence of the other two growth substances, (vii) Rooting and shoot growth in Kober cuttings were completely prevented by the antiauxin MH at 250 and 500 ppm, and at 1,000 ppm it proved lethal. Thus, the shy rooting character of this clone cannot be due to an excess of natural auxins. Rooting in Malbeck and Kober was stimulated by TIBA at 1 and 3 ppm. (viii) At 25 and 50 ppm both NAA and IBA increased rooting (except for the higher NAA concentration in Malbeck). In general, rooting was checked by Vitamin B complex and nicotinic acid but was stimulated by autolysed yeast extract.

The effects of endogenous growth substances on rooting in the clones Malbeck (a good rooter) and Kober 5BB (a shy rooter) were also studied by Tizio and others (Auxins and inhibitors were investigated in buds and internodes of cuttings before and after stratification. The amount of inhibitors increased towards the end of internodes than in buds. The natural rooting capacity of these clones does not suggest a close correlation with changes in endogenous growth substance content during stratification. The localization of root formation at the nodes coincides with auxin production in the buds, but does not explain the difference in the rooting capacities of the two clones. Tureckaja *et al.* in an investigation reported that in cuttings of cultivars which root readily, rooting was accompanied by a marked reduction in the content of growth inhibitors and large fluctuation in the content of growth stimulators. Cuttings of cultivars which root with difficulty had a fairly stable content of growth regulators. When vine cuttings were kept in a solution of IAA (250 mg/l) for 14 hours, those of a cultivar which rooted easily rapidly utilized the absorbed IAA, but those of a shy-rooting cultivar decomposed the absorbed IAA only slowly. When bud-brust of vine cuttings was delayed by low temperature (the temperature of the rooting medium being kept normal) there was stimulation of rooting, accompanied by migration of natural IAA from the upper to the lower part of the cuttings. Studies were made to determine the inhibitor-like subtances which affected the rooting of Malbeck vine cuttings. Ether, alcoholic and aqueous extracts were made of cuttings at the end of May, July and September and the biological activity of the inhibitor-like compounds was determined by using the, wheat coleoptile straight growth test and the mathiola seed germination test. Of 55 eluates which significantly inhibited cell elongation only 6 seemed partially to affect the rooting capacity of vine, and of 18 eluates which were inhibitory in the seed germination test, only 4 affected the rooting process. The results indicated that the rooting capacity of this cultivar was possibly regulated by the interaction of 4 inhibitor-like substances and 8 stimulants.

Basipetal centrifugation of 420 A rootstock cuttings at 1,000 r.p.m. for 30 minutes after 24 hours immersion in water increased the percentage of rooted cuttings from 27 to 47 and the average number of roots/cutting from 5.1 to 9.1. Centrifuged cuttings contained less GA-like material, particularly at the basal end, than non-centrifuged cuttings. Growth inhibitor content was also lower in centrifuged cuttings, whereas auxin-like material was much higher. Studies were carried out with the easy-to-root *Vitis vinifera cv.* Sultanina and the difficult-to-root *V. champini* cv. Dogridge. Cuttings were taken monthly between December and April from basal, central and apical parts of the shoot and the

rooting and inhibiting activity of the extracts was determined by mung bean bioassay. In Sultanina the presence of growth stimulating substances (GSS) was independent of shoot maturity whereas in Dogridge the presence of GSS was dependent on shoot maturity and there were no GSS in cuttings taken in March and April. Inhibitors were found in the extracts of cuttings of both cvs.

Zarkua reported that in vine cultivars *R. kaciteli*, 420A and 5BB callusing and root formation were found to be directly related to protein N content, but the intensity of bud formation was related to a content of non-protein N. The rate of loss of carbohydrate reserves in vine cuttings was quicker at higher temperatures. At 40°C the carbohydrate reserves were maintained until about mid-March. During stratification (at 23°C) carbohydrate reserves were rapidly used up and growth during callusing was found to be directly related to the level of carbohydrate reserves. Further rapid depletion of the carbohydrate reserves was prevented by hardening off at 8-10°C. Changes in the carbohydrate status of cuttings of Sultana vines from which plants were developed in a glasshouse were studied by dry weight measurements and analysis for sugars, starch and hemicellulose. It was concluded that plants developed from cuttings of two internodes or longer were not subjected to any degree of carbohydrate stress which might affect physiological process related to fruitfulness. Respiration data from 3-node cuttings showed increased consumption of carbohydrate reserves where NAA was applied, thus explaining the mortality of cuttings with initially poor reserves. Soaking of stored cuttings greatly increased their respiration rate at first, followed by a rapid fall to a level below that of the unsoaked cuttings. The rise was somewhat higher and the fall slightly less when the cut ends were renewed before soaking. The maximum respiration occurred, not at full hydration, but after the loss of 0.5-1% of moisture.

Cuttings from the 5 most widely used grape vine rootstock cultivars in the zone of Puglia (140 Ruggeri 17.37, 34/EM, 157, 11/C and 420A) were taken on 12 February and 12 and 25 March. There was a decrease in total sugars and sucrose with time of cuttings whereas water, nitrogen and polysaccharide content of cuttings remained constant. No relationship was found between total sugar and sucrose contents and percentage rooting. The dry weight of Delaware grape vine cuttings fell gradually for 6 days after planting and then began to increase. The soluble nitrogen content measured as a percentage of dry weight gradually decreased in both the upper and lower halves of the stem throughout the propagation period, while the insoluble N content fell markedly only in the upper half of the stem as new shoots grew. The total N content behaved similarly to that of insoluble N. Much N moved from the lower to the upper parts of the cuttings as roots and shoots began to grow. Little difference was found in the contents of starch, sugars and total carbohydrates between the lower and upper halves of the stem. The starch content generally decreased in both parts throughout the propagation period, while the total sugar content decreased markedly in 40 days after planting and then temporarily increased. One hundred days after Delaware vine cuttings were planted in sand in a plastic house, 19, 41, 34 and 6% of the dry matter was present in the new shoot, the upper and the lower halves of the old stem, and the new root, respectively. At the beginning of shoot formation there were marked P and considerable N and K movements into the new shoot and marked movement of K and Mg into the root, and by the 100th day from planting 43% N, 37% P, 49% K, 35% Ca and 50% Mg had moved from the original cutting into the new organs. A direct correlation was observed between diphenyloxidase activity and root regeneration. The appearance and growth of callus, roots and buds intensified from September onwards, as did the increase in diphenyloxidase activity. The rooting capacity of the cuttings was greatly dependent on the content of different forms of N and a direct correlation was noted between protein N content and root regeneration.

Habib *et al.* in an experiment concluded that survivability of the cutting was positively correlated with initial carbohydrate content of the cutting and negatively correlated with the initial nitrogen content. They also found that Rumi Red cuttings (high carbohydrate and low nitrogen) had the highest survival (82-

83%), while Thompson Seedless (low carbohydrate and high nitrogen) showed the lowest survivability (74-77%).

GA-like activity was detected in bursting buds of intact Delaware vines but very little in bursting buds or basal portion of the hardwood cuttings. Cytokinin activity in the buds reached a peak at bud-break in both intact vines and cuttings, while auxin activity was lower in well-rooted cuttings than in unrooted cuttings.

Basal cuttings of the grapevine cv. Carignan were taken on 20 November from 3 groups of material and treated as follows to provide a range of starch levels : (i) defoliated on 28 July at the end of shoot growth and the start of starch accumulation in the woody tissue, (ii) defoliated on 5 September (fruit maturity), and (iii) not defoliated, natural leaf fall in November. The single bud cuttings were held for a month in a cold store and inserted in a rooting medium with basal heat in mid-December. Root and shoot lengths were recorded about 50 days after bud-break, when active growth had ceased, and were found to be proportional to the initial level of starch present in the cutting. They were highest in treatment (iii) in which the starch content originally ranged from 4.5-7.5% of dry matter. Cuttings in treatment (i) contained 1-5.5% starch and those in treatment (ii) 2.5-6% starch. In case of *Vitis champini* cv. Ramsey, Treeby and Considine studied the relationship between carbohydrate metabolism during storage and cutting performance which revealed that with hardwood cuttings, no storage, cold storage and storage in sand at amibient temperature affected carbohydrate metabolism differently and subsequent propagation depended strongly on the allocation of carbohydrate reserves to the soluble fraction.

Kracke *et al.* observed that easy-to-root rootstock Kober 5BB contained a very high amount of auxin, but very low levels of GA and ABA-like substances. Whereas in the hard-to-root rootstock cv. 146 Ruggeri the level of auxin was low and it contained greater amount of GA and ABA-like substances. It was also found that during root formation, IAA-like substances increased slightly in both the rootstocks until bud-burst and decreased at root emergence. At the same time, GA-like compounds increased rapidly in 140 Ruggeri and decreased in Kober 5BB. ABA-like substances in 140 Ruggeri reached a high level, whereas in Kober 5BB it remained low. Soaking the cuttings in water enhanced the rooting ability of 140 Ruggeri and increased its IAA levels. Cuttings of the cultivars Kober 5BB (easy-to-root) and 140 Ruggeri (hard-to-root) treated with 4,000 ppm IBA or 2,000 pmm NAA, were bioassayed for endogenous hormones. Both treatments induced marked modifications in the hormonal pattern at different stages of root formation in 140 Ruggeri and to a lesser extent in Kober 5BB. Auxins doubled the IAA content and induced 2 peaks : (i) during cell multiplication at the cutting base and (ii) immediately before root emergence. In general, IBA and NAA promoted GA degradation so that after callusing the GA level was about half of that in the controls. NAA caused strong depletion of ABA in Kober 5BB and to a lesser extent in 140 Ruggeri. Both treatments prevented a rise in ABA content before root development.

Mato *el al.* observed that root formation in grapevine cv. Albarino was accompanied at first by a rise and then by a fall in total peroxidase activity in the explant. These variations occurred concomitantly with similar changes in the amount of the 3 cathodic isoperoxidases detected, the most abundant of which also exhibited IAA oxidase activity. The anodic isoperoxidase bands detected were very weak and underwent no variation during rooting. Changes in the opposite direction (a fall followed by a rise) were observed in the concentrations of certain endogenous phenolics including monoferuloyl, monocaffeoyl and mono-p-coumaroyl-tartaric acids, some of which may act as auxin protectors.

In an investigation on the lipid constituents in cuttings during after cold storage, Lavaud recorded that buds opened and rooting took place normally in cuttings from shoots stored at -5° but buds on cuttings from shoots stored at -15° did not open and no roots were formed. Study of the lipid contents of the cuttings before root initiation showed that storage of shoots at -5° caused increases in saturated, unsaturated and total fatty acid levels while storage at -15° resulted in a slight increase in saturated fatty

acids and decreases in unsaturated and total fatty acids. With storage at -5°, phospholipids decreased and neutral and glycolipids increased, while at -15° the neutral lipids remained virtually unchanged, glycolipids increased slightly and the phospholipids decreased. Lipid metabolism during the rooting period was markedly affected by storage at -15°, with degradation of neutral lipids and synthesis of polar lipids.

Anatomy of Root Formation

Investigations on rooting in vine cuttings showed that (i) all root primordia arose from between the outer part of the newly formed xylem and the phloem region; (ii) primordia became visible in 30 days after planting, and (iii) the optimum temperatures for initiation and development were different. Cuttings of 2 vine cultivars were taken in June, treated with heteroauxin at 50 mg/1 and planted in frames. In the cuttings treated with heteroauxin root initials were found in various tissues: in the expanding undifferentiated multicellular cambium, in the peripheral cells of the primary medullary rays adjoining the pericyclic fibres, in the parenchyma of the primary cortex. In the controls the root initials were found in the peripheral cells of the primary medullary ray adjoining the bast and pericyclic fibres. A histological study indicated the importance of blocks of starch storing tissue, that replace some of the phloem and xylem of outwardly deviating vascular bundles immediately below nodes, in determining the position of adventitious roots. Nearly 75% of the total number of roots arose from below the buds, about 25% from below the tendrils and very few from the lateral portions of the nodes.

The anatomical modifications in cuttings during rooting was studied by Fabbri *et al.* Callus produced by the cambium is mainly used for wound heating whereas callus from the phellogen facilitates the outward growth of newly-formed roots. At the lower end of cuttings there is cambial-type meristematic activity, the new xylem always being produced near the original xylem, towards the axis.

Two-node cuttings, taken on 15 October just before leaf fall, were treated with IBA and set to root in perlite at 25°C. Samples were examined microscopically at intervals from 0 to 30 days. Root formation appeared to involve two stages. In the first, lasting 2 weeks, no visible changes in anatomy were detected and meristematic activity was negligible. In the second stage (of similar duration to the first) abundant proliferation of the cambium and phellogen was observed. The phellogen produced callus and the cambium resumed its normal activity as well as producing local masses of undifferentiated cells which continued to divide. These masses, the root initials, were usually at the level of the medullary rays where a rapid starch hydrolysis was noted. Differentiation of vascular connections followed shortly afterwards. The resulting root primordia emerged from the stem bark between the 30th and the 40th days.

Niagara Branca scions were cleft grafted onto IAC 313 cuttings and placed in a rooting medium. Adventitious roots from IAC 313 rootstock originated from vascular ray extensions and usually emerged after 22 to 30 days. Those from leaf or branch scars, however, were more vigorous and emerged earlier. Callus formation and rooting progressed together.

Single-Bud Cutting

Single-bud cuttings without a basal node were taken on 7 dates during March, April and May and immersed in water up to the node. Calo and Liuni summarised that (i) the part of the shoot from which the cutting was taken did not affect the time taken to produce roots, (ii) cuttings taken before or after bud-burst rooted in an average time of 20 days, but those taken during bud-brust often required 30 days, (iii) rooting was not related to shoot development from the bud, and in some cases roots were produced while the bud remained dormant, (iv) the time taken to root was not correlated with the length, diameter, surface area or volume of the cutting, but was inversely related to the surface volume ratio.

In another experiment, single-bud cuttings taken at bud-burst and 1, 2 and 3 weeks earlier, were set to root in water at 18°C with the following treatments : (i) the bud untouched, (ii) the bud removed as it sprouted, (iii) the bud removed when the

cutting was taken and (iv) the bud removed when the cutting was taken and the stem partly cut through below the bud region. Time of taking the cuttings had little effect on rooting ability in treatments and rooting percentage was highest when the bud was untouched. Calo and Liuni suggested that the bud meristem directly influenced the secondary meristems (responsible for root initiation) at and also before bud-burst, and that the downward movement of a stimulatory substance was involved.

In an investigation on single-bud cuttings taken from the first 16 nodes of vine shoots and placed in vermiculite with bottom heat, the first roots were produced from the 9th - 12th nodes after 49 days in 86% of cuttings of the rootstock cv. R 110. For the rootstock cv. 41B and the hybrid 38357, the corresponding figures were 45 days and 72% and 24 days and 67% respectively. After 2½-months in the same conditions roots were produced with the greatest frequency and amount, and were longest in the region of the 9th to the 12th node. The frequency with which these nodes had rooted in R 110 was : 9th node 77%, 10th node 94%, 11th node 90% and 12th node 77%. The corresponding figures for 41 B were 60, 100, 100, 100 and for S 8357 70, 100, 100, 90. The 3rd or 6th node, depending on cultivar, showed better than average rooting capacity .

Treatment of single-node cuttings of the cultivar Cardinal with 0.01% NAA for 12 hours reversed th normal order of root and shoot formation, in some cases completely suppressing the latter. In cuttings of , 1½ and 1½ internodes and without basal nodes, treated over the whole internodal surface with 0.01% NAA for 12 hours, root formation followed shoot formation and was confined to the basal 2 cm kept in water, the delay being related positively to the length of the cutting. Cuttings of $^1/_3$ and $^1/_2$ internode with the node at the upper end, treated only at their bases and kept vertical in sawdust, formed weak shoots and a few roots at the node.

Effect of time of taking cuttings and presence of bud was studied on single-node cutting taken at 8 days interval from 20 March to 13 April. The controls were left intact and the rest disbudded either (i) by pulling the bud off or (ii) by cutting across the stem just below it. Within 60 days all the intact cuttings and all the latest taken (i) cuttings had rooted. Of the earliest taken disbudded cuttings, 66% in the (i) group and only 22% in the (ii) group had rooted. There was 90% rooting in both lots of April cuttings in treatment (ii) and in late March and early April cuttings in treatment (i) .

Calo carried out an experiment on the effect of various factors on rooting in single-bud 5 cm long cuttings of Merlot vine taken at an interval of 10 days from 10 November to 10 April and kept in water at 18°C. After one half of them had been treated at the apical end with 40 ppm IAA for 24 hours the single bud was allowed to develop normally, or was cut off at the time of bud-break or 3, 6 or 9 days later or the apex was removed 6 or 9 days after bud-break. The time taken for the buds to shoot was increased by IAA treatment in cuttings taken at the end of November or later, although IAA generally hastened rooting. The time when the cuttings were taken also affected the speed of rooting, which increased with successive cutting dates after 30 January, until it suddenly fell in cuttings taken around 30 March, i.e., just before the time of bud-break in the field. IAA treatment while hastening rooting, did not alter this pattern. Removal of buds after bud-break did not affect the speed of rooting, though this was highest in the untreated control and cuttings with the apices removed; IAA application reduced these difference between treatments. The total length of roots produced by each cutting was greatest in cuttings taken during post-dormancy (i.e., when rooting was slow) and again after bud-break (when the cuttings rooted readily); residual differences from the previous season may have accounted for the post-dormancy effect. The position of the roots was influenced by the time of taking the cuttings, in cuttings taken during post-dormancy most roots were produced at the apical end of the cutting, but on later cuttings more were produced at the basal end. The transectional quarter of the cutting containing the bud produced more roots than the other 3 sectors.

Single-bud cuttings of Merlot vines were taken during dormancy, just before bud-break or during bud-break and half of each group was treated for 24 hours in 40 ppm IAA. Combined

with these treatments was the removal of the bud with 0, 1 or 2 cm of stem at 0, 24 or 48 hours after taking the cutting from the mother plant. It was concluded from the results of the experiment that rooting is under the direct control of the bud which both receives and transmits the necessary stimulus; this stimulus is produced at the moment when the cutting is taken from the parent plant and can manifest itself during the first 24 or 48 hours after detachment; detachment from the parent redirects the metabolism of the cutting towards a general process of growth of which root formation is a part; endogenous auxin-like substances carry the rhizogenic stimulus and their concentration is greatest near the bud, becoming less towards the base of the cutting.

Graded, single-bud cuttings of the vine cv. Armenija were treated with a suspension of azotobacterin or manure solution and were set in sand. Both treatments increased the number of micro-organisms including azotobacter on the roots and improved rooting and shoot growth compared with the controls.

Single-bud cuttings of vine rooted much better in water than in nutrient solution. Rooting in sand gave satisfactory results, but was not so reliable as in water. Treatment of cuttings with NAA gave poor results both in sand and water.

From the results of the experiments on single-bud cutting, Eccher and Marro, concluded that soaking in hot (30 °C) or cold (5°C) water reduced the rooting capacity of fresh cuttings. The longer the soaking, the greater was the reduction, and the use of running water had a greater effect than soaking. A vine internode extract stimulated rooting in the presence or absence of 30 ppm NAA. Rooting was reduced by storing cuttings for 8 days in unsealed plastic warps, especially if followed by a 2-hour exposure to dry air. The poor rooting of the latter exposed cuttings was improved by soaking for 3 or 6 hours, the shorter time being more effective. Rooting of the other stored cuttings was reduced by the longer, and improved by the shorter soaking. The rooting of grafted cuttings of the cv. 3309 was markedly enhanced by dipping in NAA at 150-300 ppm. However, in the previous year NAA at 250 ppm substantially reduced the rooting in cultivars 420A and 140 Ruggeri. A high toxicity of NAA was also revealed by the high percentage mortality of cuttings within 22 days after a 6-hour treatment with 30 ppm NAA, especially in the presence of 5% glucose.

Liuni in an experiment on single budded Merlot cuttings taken at intervals between 20 October and 5 April, placed some to root at once and the others were stored at 4°C in plastic bags for 6 months and then put to root with or without the bud removed. In each treatment the base or apex of the cutting was treated with 40 ppm IAA or water. Cold storage had little effect on percentage shooting in cuttings taken before early February (the end of post-dormancy and the start of the pre-shooting phase) but in cuttings taken later shooting was much reduced. Percentage shooting was better in water than in IAA treatment and in basal than in apical application. The time of shooting was shortened by cold storage, but the elongating capacity of the shoots was adversely affected. Cold storage greatly reduced the percentage of cuttings which rooted; rooting was highest among cuttings taken at the pre-shooting stage in February and early March. The time to root was slightly shortened by cold storage but the length of roots produced was much depressed, and the presence of the bud and the various apical treatments further depressed it. Length of roots was greatest in cuttings taken in February and early March.

In trials with the difficult-to-root European Amur hybrid cultivars Fioletovyi Pannii and Saperavi Severnyi and the relatively easy rooting European cv. Aligote, softwood cuttings with one bud were taken before flowering from renewal spurs, lateral and fruiting shoots and from suckers. During rooting, substrate temperature 5 cm deep was maintained at 30-38 °C. Roots appeared in 8-9 days after planting and shoot growth started 10 days later. Cutting from renewal spurs gave the best strike (96.2%), followed by those from fruiting shoots (85.0%). The 2 hybrid cultivars produced moderate amounts of callus and plenty of roots, whereas in Aligote the opposite was true.

The cuttings consisting of a leaf and a bud in the axil were rooted in a 2 : 1 mixture of sand and wood shavings at 20-25°C and high humidity. Rooting of single-bud cuttings was normally

achieved in 2-3 weeks and might be accelerated by keeping the base of the cuttings at a constant temperature of 18-20°C. Basal cuttings were best for Cabernet Sauvignon and terminal cuttings for cv. 1613.

Woody scions of cv. Merlot with a single bud were put to root in a growth chamber and the respiratory intensity and peroxidase, polyphenoloxidase activity were studied. During the root formation in single-bud cuttings, Iannini *et al.* recorded that respiratory and enzymic activity changed little in the woody parts but became very intense in the newly formed organs, especially the shoot. Phenolic compounds increased markedly towards the end of the observations.

Harvesting of canes in autumn about 20 days after leaf fall or in spring between the bleeding stage and the stage of bud formation was advised. Segments taken from the middle or lower part of the canes made the best cuttings. Single-bud cuttings were best severed 0.2-0.5 cm below the node.

Basal, mid-stem and apical single-bud cuttings of 2 cultivars (Nuragus and Trebbiano) taken at intervals from July to February were, or were not kept at 7°C for 20 days before planting in a growth chamber at 20°C and 4,000 lux in 16-hour day. In both cultivars the break of bud rest occurred in the first 10 days of August and DD 50 values (time required to reach 50% bud burst) decreased progessively with cutting date from July to February, the drop being more rapid in Nuragus than in Trebbiano. Shooting and rooting increased as DD 50 fell. Low temperature also increased shooting and rooting, especially with basal and mid-stem cuttings.

Temperature was found to influence rooting in single budded cuttings of 22 cultivars packed on moss in boxes held at -6 or +1°C for a month and put to root at 13, 18 or 23°C. Only in those held at 13°C the pre-treatment cooling temperature affected rooting, which was more rapid after +1°C pre-treatment. Rooting and shooting did not appear to be antagonistic processes and time to rooting and time to shooting were positively correlated. Both were least at 23°C, and root and shoot weights and lengths were highest at this temperature.

Layering

Mound-layering is often practised in grapes to replace the missing plants in a row. In this method a vigorous shoot from a neighbouring vine was allowed to grow to its full length and in the following spring when it reached 4 to 5 m length was tied by a wire and buried 45-65 cm deep along the rows with the tips outside. This was further cut back as individual plants, but the new plants remained connected with one another. Muthukrishnan and Venkataramani observed satisfactory root formation in air-layers when the shoots were treated with 5,000 ppm IBA in a 50 per cent alcoholic solution.

Tudosie and Sarca reported that layering at a depth of 30 cm gave 17.25 per cent increase in the number of rooted plants, compared to layering at 45 cm depth.

The method of producing new vine bushes by means of layering of 2-2.5 m long shoots and their subsequent training was described by Taran Vine thus propagated and trained produced during the 3rd year 3 times more grapes than conventionally propagated vines.

GRAFTING

Methods

A succesful method of grafting of grapes was reported by Woodfin. The graft was simple splice or whip graft without tongue when the grapes were in flower. Both stock and scion should be quite green and tough to withstand bending without snapping. About 95-100 per cent success was recorded with this method. Top working of inferior cultivar was suggested by Mattras and he reported over 90 per cent success in grafting. By the end of September the plants showed exceptional vigour.

Tavadze in an experiment used *vinifera* scions of Rkaziteli, grafted on the American rootstock, RipariaxRupestris 420A and the scion containing buds situated at different levels on the selected wood, was inserted on pieces of rootstock material taken from apical, middle and basal positions on vine shoots at Telav, Georgia, USSR; 1,200 grafts were made in all. It was found that

fine lignified apical portion of the American vine formed the best union, despite the fact that in practice they were usually not used for the purpose.

A form of grafting was recommended for the provinces of Bologna and Ravenna because of the excellent conditions for growth. The method was especially recommended for European vines on Kober 5BB stocks (Capucci 1940). Although budding of vines was not usual in South Africa, Yema grafting was a successful method of propagation. Cleft grafting with hardwood scions should take the place of softwood splice or whip and tongue grafting when grafting material was scarce or rubber bands for keeping the grafts in position were unobtainable. The grafts were inserted at a height of 150-180 cm from the ground. Softwood grafting of vines as employed in Hungary was useful for replacements and for top-grafting 'direct producers'. It is important to choose graft shoots at the right stage of development.

Two new methods of grafting were described by Branas which were carried out at the end of summer when the vines had a second growth. The rootstock was allowed to grow *in situ* and the scion was taken from shoots that were lignified and the rootstocks were trimmed for 'Mayorquine' and 'Cadillac' methods of operation. The former was said to be difficult to do by hand, but can be done mechanically, while for 'Cadillac' method oblique cut was more easier. In both the methods, union was found to occur during autumn, but the bud remained dormant until spring.

Results of experiments with over 50,000 grafts had shown that gill cut (a series of interlocking teeth cut on the stock and the scion) was the most satisfactory type of cut for grafting. With the aid of a specially constructed cutting machine operated by a small electric motor, 22,000 grafts can be completed in a day.

Mexwell recommended that vines should be grafted after being set in their permanent sites, as this was proved more successful than the normal bench grafting. The rootstocks should be cleft grafted within 7 days of planting, and the grafts earthed up to just below the top bud of the scion until union had taken place to prevent drying out.

In trials with the *V. vinifera* cv. Tempranillo de Rioja on Rupestris du Lot equally good results were obtained with manual whip and tongue grafting and grafting by the 'Mendocino modificado' and 'Instituto' methods in which the cuts were made with an electric circular saw operating at 3,000 r.p.m. Grafts made by these two methods resemble the whip and tongue graft except the tongue and groove had parallel sides and square ends.

Scion wood, cold stored during the winter, was successfully grafted on green shoots of 2 bud cuttings in the second spring after these had rooted. The use of PVC tubes and paraffin greatly improved the percentage take, but the method was recommended only for small scale production.

Bark grafting at a high level (30-36 inch) was nearly as successful as were cleft and notch grafting. It was more successful than bark grafting at a low level (4-6 inch). Vines bark grafted later in the season produced less growth of the scion shoots. Bark grafting could be accomplished successfully throughout the season as long as the bark slipped, and could be done by less skilled worker, and with less effort, than cleft or notch grafting.

Successful tests were made with scion from vines already in leaf. After removing shoots emerging form the main buds, the scions were shaped for whip grafting in pairs so that their bases united laterally with each other and axially with the rootstock. Each scion produced 1 or 2 shoots from the secondary buds, and these were left to grow during the current season. Copius callus formation and thus a firm union had been ensured by leaving a shoot ridge at the top of the scions to project a few mm beyond this.

Italia vines on Rupestris du Lot were replaced by Cardinal and Moscato dell' Adda in some cases by wedge grafting with softwood scions at the top of the Italia trunk and in others by wedge grafting with hardwood scions after cutting back to the rootstocks. Alphonse Lavalle was also used in the latter case. The second method produced the higher percentage of successful grafts and firmer unions, more vigorous scion growth, more profuse flowering and high yield.

Pearl of Csaba scions were cleft grafted onto 1-year-old rooted cuttings of *Vitis labrusca* cv. Large white, and a ball of grafting clay (2 parts clay + 1 part cowdung) was tied round the union. When the grafts were planted with the union above the soil surface the percentage of take was 83.3, whereas it was only 66.6 when the union was below the soil surface.

A green grafting technique for indexing grapevines consists of joining actively growing stock and scion tissues with a plastic or rubber tie. This has some advantages over the more generally used dormant chip-budding method, as it can be done for the greater part of the growing season, and very small stocks and scions can be grafted. It also provides a more rapid means of testing for fan leaf virus than does chip-budding.

A technique was described wherby plant breeders may bring vine seedlings into fruit production very rapidly. Seeds were sown in February and after 70 days the tips of the seedlings were side-grafted onto established vines with a diameter of $^1/_4$ inch or more, using a T-shaped incision. The union was warped with clean polythene tape, which was gradually removed after 14-21 days. The scions made cane growth up to 30 ft in length in one growing season and fruit production was obtained in the year following grafting.

Using one-year old rootstocks of the cultivars Hur and Kandhari and scions of Pearl of Csaba, Bhokri, Himrod and Motia, the results of cleft and notch grafting were compared. The stocks were lifted and cut to 6-8 cm from the base and had all buds removed. The scions were cut to leave 2-3 buds. The grafts were planted with the union just above ground level and soil was mounded up around them until the scion was completely covered. The mounds were kept moist, and when the buds began to sprout the soil round the union was removed. The time taken for the first bud to sprout ranged from 33 to 61 days with cleft grafting and from 56 to 63 days with notch grafting, depending on the cultivar, and complete sprouting took a further 13-24 and 11-17 days, respectively. The success of cleft grafting varied between 50% and 90%, the cv. Motia on Kandhari stock giving only 50% success as compared to 80% and 90% success with Pearl of Csaba and Himrod, respectively on the same stock. Notch grafting gave 60-80%.

In Australia, green grafting was done in late November or early December when the pith of the growing shoots began to whiten. Since both stock and scion were green and the shoots had not started to ripen, the graft callused quickly. The rootstocks were generally grafted in the vineyard in their second or third growing season from planting as cuttings.

Gvelisiani developed an improved method of grafting. A cut $^2/_3$ the thickness of the scion was made 3 cm below the apical bud, the sharpened tip of the rootstock was inserted and the component parts tied together forming an inverted Y. The grafts without preliminary stratification were planted directly in the nursery 28-30 cm deep. Roots formed on both stock and scion and gave 70-80% of standard transplants. This method considerably reduced the production costs and because of the double root system, resulted in strong high-yielding plants which developed normally even on plots infested with phylloxera.

Jansen reported the results of 4 trials with *vinifera* vines. Cleft and notch grafts, made 2-3 ft above ground level, were equally successful although the notch grafts made smoother unions. Bard grafts were less successfull. Notch grafts made in mid-April, about a month after bud-burst but before bark slippage, were as successful as earlier grafting, or more so. Painting the scions and grafting compound (asphalt-water emulsion) with white latex or vinyl paint improved the results.

Bud slips from well-developed non-lignified scion shoots were bound to the rootstock cutting with soft thread and the air around the union was kept moist by enclosing in a transparent plastic bag in which one or two rootstock leaves were included, the bag was removed after 12-15 days. Graft take was 73.7% in the first half of May compared with 57.7% of made in late May.

Alley claimed that wedge graft was an improvement over the notch graft as it was easier and faster. It required less skill than the notch graft, could be done high on the plant and gave a good take (90%). He also described that side-whip graft ensured

greater cambium to cambium contact than split grafting. The greater take and the faster return to normal vigorous growth obtained by this method were compared.

The method described by Richards involved saddle grafting in spring on rootstock cuttings in which roots were initiated by bottom heat but did not emerge. The cuttings and scions were machine prepared for grafting and tied and waxed by hand. The grafts were then potted in 2 inch diameter plastic tubes and held under glass at 75-80°F. Callusing was visible in 10-12 days and was followed by rapid shoot growth and root development. Three successive batches of grafted plants could be produced in one season.

To shorten and simplify the production of grapevine planting material, softwood shoots 7-10 mm in diameter were taken in Jully from scion cultivars, Cabernet Sauvignon and Italia, and the rootstock cultivar was Berlandieri × Riparia Kober 5BB. Grafting was made conventionally and the 2 components were tied with a polythene band. The grafts were planted 5-7 cm deep, maintained under mist and protected against temperature extremes for about 15-17 days. Subsequently the rooted plants were gradually hardened until late October, when they were ready for transplanting. This method gave 50-60 per cent success for the 2 cultivars and was economically more viable than the conventional method requiring stratification. In France, cleft grafting on 2 shoots/plant was carried out at the end of March, using long (5-bud) scions previously treated with paraffin wax. The graft union was protected by an inverted bottle filled with soil or river sand. The bottle neck was split longitudinally in August and the bottle itself was removed in winter and spring. Fruiting occurred the following summer.

Albertse and Saayman reported that chip grafting and amphi (or boat) grafting were very effective for re-grafting mature grapevines with new scion cultivars provided that they are healthy and growing vigorously. Aerial grafting is highly successful and cost-effective.

Reustle *et al.* conducted green grafting trials with grape cvs. Riesling, Orion, Trollonger and Regent and rootstock Kober 5BB, 26G and 125AA under greenhouse condition. They observed that presence of leaf promoted rooting and grafts. The scion leaf was found important for callus formation and its removal was found to reduce grafting success and survival.

In an experiment on success in grafting in tropical condition, scions of cv. Queen were grafted onto rooted or unrooted cuttings of Criolla Negra. The grafted material was placed in sand-filled 5-litre polyethylene bags and maintained partly shaded and irrigated twice a week. Percentage take 75 days after grafting was higher on rooted than on unrooted cuttings and was highest with lateral whip grafting (81.7%), followed by shield budding or cleft grafting (both 73.3%), and splice grafting (65.0%). Percentage mortality after bud burst was similar on rooted and unrooted cuttings (11.3 and 11.7% respectively).

Effect of Rootstock on Graft Union

In the experiments carried out by Vidal *et al.* with different rootstocks between the years 1925 and 1931, some 5,000 grafting operations were done on 41B, Rupestris du Lot, 3300, 1202, 93-5 and others. The authors noted that (i) grafting with cultivars such as 34 EM, 157-11 was difficult owing to their small production of sufficiently strong wood, (ii) certain hybrids which at first made an excellent show in the nursery often failed later owing to faulty union, (iii) Berlandieri hybrids were liable to delay the emergence of roots, a fact which gave rise to imperfect plants, a very favourable temperature being essential to hasten root emergence. Coupin observed that the use of American stock containing Berlandieri blood proved very successful in grafting the vine in the field. The best result with bench-grafting in New Zealand had been achieved with Mourvedre × Rupestris 1202 stock, good result was also obtained with Baco No. 1. In Rumania, grafting of vines on the morphologically basal end of the rootstock resulted in better union and with this method Italian Riesling or Kober 6BB showed 91.3 per cent take, compared to 54 per cent in the old method. In comparative trials on grafting with some important grape cultivars on different rootstocks, all the combinations of 10 cultivars and 9 rootstocks were tried. Of the

rootstocks, Berlandierix Riparia selection Craciunel 2 proved the most satisfactory as regards minimum loss of grafts (14.11 per cent), producing the largest number of plants with well-developed root system (58.46 per cent), good graft-union (49.94 per cent) and first quality transplants (44.3 per cent) . Avramov and Jokovic observed variation in the degree of callus formation in different rootstocks. Among the 24 rootstocks tested the majority gave poor results. The highest level of success (50% top quality plants) was obtained with Aest.-Mont.-Rip.-Rup. 554.5, followed by Berl.xRup. 770 Paulsen. In a subsequent test with the orginal 24 and 6 additional rootstocks, 53% first class plants were obtained with Berl. × Rip.157.11 and 48% with Aest.-Mont.-Rip.-Rup. 5545. In both tests all the scions on Mouv. × Rup. 1202 died. The principal difficulty in grafting this cultivar is the fact that its stems had a very high proportion of pith to wood.

In trials carried out in 1964-66, involving from 965 to 2,040 grafts on each rootstock, the production of first class grafts of cv. Cardinal on Rupestris du Lot averaged 32.06%, on Chasselas × Berlandieri 41B 31.28% and on Berlandieri × Riparia Kober 5BB 28.39%. The proportion of good plants prodeced on the rootstock Chasselas × Berlandieri 41B was rather variable. The rootstock 41B, Solonis × Othello 1613, Salt Creek and Dogridge were tested in combination with 4 scion cultivars. Salt Creek and Dogridge gave the best results and 41B was least satisfactory. Salt Creak and Dogridge were particularly successful with Perlette and Cardinal, but less so with Dabouki and Alphonse. The Perlette-Salt Creek combination gave by far the best results. No defects of importance were observed with any of the combinations, except for a slight Zn deficiency on the vigorous rootstocks. Cardinal vines were grafted on 34 different rootstocks and first class rooted vines were obtained on Berlandieri × Riparia 301A (59.0%), Rupestris Gaite (59.0%) and Aramon × Rupestris Ganzin I (67.0%). The fewest were on Riparia × Rupestris 3303 (20.0%), Mourvedre × Rupestris 1202 (20.0%) and Rupestiris × Berlandieri (0.2)%).

Samborskii reported largest number of well-developed transplants in case of aligote on Berlandieri × Riparia Teleki 8B; Riesling on Berlandieri × Riparia Kober 5BB; Cabernet Sauvignon on Berlandieri × Riperia Kober 5BB and Sorok let Oktyabrya on Berlandieri × Riparia Teleki 5C. In a trial, vines were bench-grafted by the whip and tongue method with cultivars Pais and Carignan as rootstock and Cabernet Sauvignon, Muscat of Alexandria, Muscut Amiralla Semilon, Cote Rouge, Merlot, Riesling as scions. There was no difference among the different scions in respect of callus development after 17-51 days. In an experiment, Mortensen concluded that out of 11 rootstocks tried, the cultivar Dogridge gave the highest yield and vigour as well as high percentage of successful union with all the scion cultivars grafted on it. The grafts potted in finn pots and peat pots and grown for 6 weeks in heated plastic house gave 80 to 95% take, compared to 25-30% obtained by the current commercial method. Take was good between the scion cultivars Riesling, Aligote or Chasselas and the rootstock cv. Riparia × Rupestris 101-14. Chasselas gave the highest number of grafts with a fully developed callus; the poorest results were obtained from Cabernet grafted on Riparia × Rupestris 101-14 or Kober 5BB rootstocks. Growth was slightly better in paraffin than in non-paraffin treated grafts .

In Egypt, three rootstocks were compared. Hybrid No. 22 produced the largest number of high quality grafts and well-developed transplants on Kober 5BB, Tbilis was best on Riparia × Rupestris 3309, followed by Chásselas × Berlandieri 41B. Steinhauer *et al.* in their experiment with four methods, viz., ground level wedge grafting, high level wedge grafting, chip and T-budding, in Carbernet Sauvignon and Merlot vines on Aramon × Rupestris Ganzin No. 1 rootstocks grown at two localities, observed that the high wedge grafting gave significantly lower graft take, while the low wedge graft gave good results in one locality but poor in another. Chip and T-budding showed good results at both the places with bud take ranging from 66 to 77 per cent. Graft incompatibility between *V. rotundifolia* cultivars and *V. vinifera* cv. Cabernet Sauvignon was overcome by softwood grafting. Incompatibility symptoms appered after 1 year's growth of Cabernet Sauvignon on *V. rotundifolia* cultivars Carlos and Male, but no symptoms occurred in Yuga or Noble. Examinations of the graft union suggested that the symptoms might be related to

a translocated incompatibility (Bouquet, 1980). Percentages of successful grafts of Muscat of Hamburg cuttings on unrooted and rooted Berlandieri hybrid rootstock 99R cuttings were 18.6 and 62.9, respectively. Corresponding percentages for the same scion on 41B rootstock were 41.5 and 58.6; first grade grapevines produced were 12.8 and 40.0 on 99R and 28.6 and 34.3 on 41 B.

In a nursery of grafted cuttings of grapevine cv. Merlot on SO4 rootstocks about 1 per cent of plants showed reddening and rootstocks splitting. Before stratification the cuttings had been dipped in Rebwachs WF (0.1% of 2, 5-dichlorobenzoic acid) grafting wax at 50g/100 plants at 75°C and after stratification in Ciragref 80 at 1 kg/100 plants at 75-85°C, and before planting the heels of grafted cuttings had been dipped in Exuberone (0.4% IBA) at 0.5 litre water for 2,500 plants. Microscopic examination showed the secondary formation of necrotic tissue due to cambial malfunction.

During union formation in compatible (cv. Carignan on 99 Richter rootstock) and incompatible (cv. Jaovment on 57 Richter) splice grafts, differences only appeared after about 30 days at the vascular connection stage. In a 3-year trial with 12 grapevine rootstocks the best graft union development (97.6%) was obtained on Rupestris du Lot and Berlandieri × Rupestris Richter 110. However, production of first grade grafted transplants was highest (41.8%) on Berlandieri × Riparia 420A 32, with 65.3% graft union development.

The scion cultivars Pearl of Csaba, Perlette and Bharat Early were grafted in January on 2 hardy and vigorous cultivars, Kandhari and Gulabi. Grafting success was greatest (100%) with Pearl of Csaba on Kandhari followed by Bharat Early on Kandhari (93.3%); success on Gulabi ranged from 80 to 83.3%. Gulabi was generally more vigorous than Kandhari.

In an experiment, Arneis CN clones 30, 19 and 15 were cleft grafted (traditional method) or chip budded onto already-rooted cuttings of 41IB, 779P, 420A, 140Ru and Rupestris du Lot. The first two rootstocks proved the least successful. Responses to the two grafting methods were similar regarding percentage take and vegetative development but bud break in the following year was rather later with chip-budding, a distinct advantage in northern Italy where the spring frosts occur. All the clones responded well to grafting on rooted cuttings. Arneis CN 19 produced most (98%) successful grafts.

Effect of Season

Bench grafting was performed satisfactorily at any time during the dormant season, but the grafts made in February showed a consistently higher survival rate than those made earlier. Callusing the grafts at 80°F for 3 weeks before planting was not necessary provided the scions were covered with sand at the time of planting. Grafts made early in the winter were kept dormant by storage at 33-36°F in polythene bags .

Grafting in February instead of March- April and hardening for 15 days at 12-15°C and storage at 5-8°C in a layer of drysaw dust until planting time showed no significant difference in the output of first class transplants between vines grafted in February and those grafted in April.

In a trial with 10 grapevine cultivars the absence of deep dormancy in the tissues of cuttings was demonstrated by the fact that both callus and roots could be induced to form at any time in favourable conditions. This meant that grafts made in December and January had suitable callus at the union, with minimal bud or root development on the scion and stock components, respectively. These grafts were then planted out in April. February grafts were hardened immediately after stratification, planted into cardboard containers, grown in greenhouses during March-April and planted out in May into permanent positions.

In an experiment with 3 grapevine cultivars grafting was carried out in (a) January-February, and (b) March-April. Average percentage of first grade plants were as follows : for Aligote 32% with (a) and 31.2% with (b), for Traminer Roter 35% with (a) and 40% with (b), and for Merlot 36% with (a) and 41% with (b) Grapevine cv. Merlot were cleft grafted onto Berlandieri × Riparia SO4 rootstock on 5 dates (10, 20 and 30 July and 9 and 19 August). Take improved with delay in grafting date but no differences were observed in shoot length and girth and in the number of leaves/vine.

Effect of Growth Substances and Other Chemicals

A considerable increase in growth was obtained by spraying the bundled grafts with a solution of heteroauxin as well as by a short immersion of the cut surface of both graft partners before they combined. Phenylacetic acid proved effective in increasing the percentage swelling of the grafts. A better take in grafting the grapevine after treating both cut surfaces with a solution of indolyacetic acid and also by painting round the graft joint with the solution was recorded by Van Der Lek.

Dragas and Avramov noted that application of IAA was very effective for healthy callus formation and good graft-union, compared to NAA and Roche 202. In Bulgaria, the union of the important red wine cultivar Mavdur with Rupestris du Lot was unsatisfactory because the scion began to form callus 6 days before the rootstock. To hasten callus formation on the rootstock, cuttings were stratified or treated with 2, 4-D or 2, 4-DB before grafting and to retard callus formation of the scion, graft wood was treated with hydroquinone. The best union resulting in the highest percentage of top quality graft was obtained when the tips of the rootstocks were soaked in 2, 4-DB at 1 mg/1 for 15 hours and the scions in hydroquinone at 2 g/1 for 15 hours . Koberidze obtained high percentage of success when both the rootstock and the scion were soaked in NAA at 10 mg/1 for 24 hours and the grafts were held in a glasshouse for 8 days before planting out. Kolesnik reported that treatment with 0.0012 per cent sodium humate improved root formation, callusing and graft union. The treatment was most effective when two applications were made, one at the time of stratification of the graft and the other at the time of planting.

Cuttings of the rootstock Chasselas × Berlandieri 41B were treated with solutions of hydroquinone, potassium bromide and heteroauxin at a concentration of 0.2%, 0.1% and 0.01%, respectively for 15 hours before grafting with scions of the cv. Bolgar, and they were then stratified. The contents of bios in the grafts, which increased at the beginning of stratification and then decreased, were higher in the treated grafts than in the untreated controls. By the end of stratification the treated grafts had developed more callus and shoot than root. The best results were obtained with the heteroauxin treatment followed by hydroquinone and potassium bromide.

Stepanova observed that treatment with IAA at 0.01 per cent, IBA at 0.005 per cent, NAA at 0.006 per cent, Vitamin C at 250 mg/1 and Vitamin B_1 at 200 mg/1 improved callus formation on vine rootstocks and also root formation.

Koch and Liebig reported that Chinosal W (8-hydroxyquinoline salt) promoted callus formation in the graft-union. Gartner obtained higher percentage of graft union by storing grafts of vine in polythene bags compared to sand covering, and the use of Chinosal and liquid Albisal proved effective in the control of *Botrytis cinerea* during storage. Immersion for 2 hours in a 0.5% solution of Chinosol protected scions and rootstocks from *Botryolinia fuckeliana* and *Phomopsis viticola*.

Grafted and rooted cuttings of 3 grapevine cultivars on Kober 5BB were variously treated and then stored at 2°C±3°C. Of the two fungicides (100 or 200 g/hl) in which the cuttings were immersed by Moretti 8- hydroxyquinoline sulphate was only fully effective against *Botrytis cinerea* infection on Chardonnay and Moscato Bianco (Muscat blanc), both characterized by a high degree of lignification and only if the roots were well washed of substrate before treatment. Thiophanate-methyl, although more costly, is recommended. It was effective on these two cultivars and the softer highly susceptible cv. Regina.

Lyakhevich recorded 81.2 to 84.2 per cent first grade transplants of Cabarnet Sauvignon and Coarna Neagra grafts stratified and supplemented with hydroponic solution and heterouxin at 0.005 per cent compared to 66.6-76.0 per cent in control.

IBA was applied at 1,000, 4,000 or 8,000 ppm to be base of grapevine cuttings and/or IAA at 1,000 ppm was applied to the grafted surfaces. The highest success rates of 75-85% on Kober

5BB and 62-80% on 420A were noticed by using 1,000 or 4,000 ppm IBA with or without waxing, 1,000 ppm IAA with or without waxing and waxing alone. The individual treatments giving the best results were paraffin waxing alone for Kober 5BB and waxing+IAA application for 420A. The success rate was low when 8,000 ppm IBA was used and when both IBA and IAA were used.

Apical or basal ends of Kober 5BB cuttings were immersed for 12 hours in water or 40 or 100 ppm IAA. These cuttings and an untreated control were then grafted with Merlot scions and put to stratify in sawdust at 26°C. After 20 days all the cuttings produced good graft callus regardless of treatments. Total root production was increased by all the treatments; water and 40 ppm IBA showed similar effects and 100 ppm IAA had rather greater effect. In all cases apical treatment caused greater root production than basal treatment, particularly in the region of scion.

The best pre-grafting treatments of rootstock material consisted of stratifying the upper part of the cutting, treatment with NAA at 0.006% or soaking for 3 days in water at 30°C. The treatments improved root and callus development during subsequent standard stratification and had a beneficial effect on the production and quality of the grafted material.

Studies were carried out on the vine cv. Muscat Yantarnyl grafted on Riparia × Rupestris 101-14. The length of rootstock was 45-50 cm and the graft union was treated with IAA at 0.005-0.01% before stratification on sawdust with heating. The treatment increased the production of first grade transplants by up to 15%. Soaking Solonis × Riparia 1616 vine rootstock cuttings in 50 ppm NAA for 24 hours before grafting gave the highest rate of graft success. In studies with the scion cvs. Aligote and Cabernet Sauvignon and the rootstock RipariaxRuperstris 101-14, soaking the scion and stock components in Chlormequat at 0.1% stimulated callus formation, rooting, shoot formation, photosynthesis and the production of high quality planting material.

Bulak *et al.* reported that in grapevine cultivars Aligote and Bastardo Magarachskii on Riparia × Rupestris 101-104 rootstock, irradiating the basal ends of the rootstock with 0.5 k-rad stimulated rooting and addition of GA_3 at 0.01 per cent to the forcing solution stimulated the development of buds and made them more susceptible to irradiation.

In order to test the effect of hormones, grapevine cv. Grenache N scions were kept for 8 hours with their tips or bases in IAA, IBA or NAA at 4×10^{-5} M or 10^{-4} M before bench grafting on SO4 rootstock cutting. After 15 days callus formation was more advanced where scion tips had been treated with IAA or IBA compared with NAA or control. In all scions hormone treatment, specially with NAA, led to increased rooting of grafted cuttings. In the nursery, grafts treated with NAA at 4×10^{-5} M grew faster than other treated grafts and controls.

Scion (cv. Rkatsiteli) and rootstock (CO-4) shoots were dipped in CCC (Chlormequat) at 0.6-1.5% for 2 or 10 seconds or 1-5 minutes. The highest percentage (91.3) of grafts with a round callus was obtained by dipping both components for two seconds in 1.5% CCC (69% in the control). In another trial, a 2-second dip of the scion shoot (2 cvs.) and the apex only of the rootstock shoot (Kober 5BB) in 2-3% CCC gave 80-87% grafts with a round callus in the cv. Bastardo Magarachskii, and 93-95% in Aligote, with 79 and 85% in the control, respectively. The results of four years experiments on several graft combinations using a range of simple solutions, mixtures and commercial products containing growth regulators (IBA, IAA, NAA, daminozide, MH) were reported. The use of growth regulators, especially at high concentrations, had differing and often adverse effects on the production of marketable rooted cuttings and was not recommended.

Maltabar *et al.* observed that addition of Chesnokov's nutrient solution improved rooting of grafts and the highest rooting of 68.2 per cent was recorded by planting 4 rows of grafts in trenches of 70-100 cm wide and 45-50 cm deep lined with thick plastic sheets and filled with peat, soil and sand mixture (2:1:1).

Application of succinic acid at 0.005 per cent plus manganese at 0.03 per cent to the grafts hardened in the open, significantly increased the physiological activity of enzymes and thus enhanced the shoot growth and increased the number of grafts.

Dipping rootstock shoots of the cv. Rkatsiteli in 0.0023 per cent succinic acid was found to stimulate succinate dehydrogenase, ascorbinate oxidase and polyphenol oxidase activities. This treatment also induced chlorophyll synthesis and stimulated shoot growth for the production of first grade transplants.

Experiements were conducted on the effects of physical and chemical treatments on the formation of callus and root development on vine grafts. Callus formation increased with a rise in temperature in the range of 20° to 30°C, but root development was not affected. Treatment with nutrient solutions or minor elements had little effect, but the use of growth susbtances gave good results. Florigen treatment increased the number of well rooted vines by 18.8%. In the same experiment, preparations based on chlorinated benzoic acid considerably increased callus formation and extended it even into the period of active vegetative growth.

Schenk also studied the factors influencing callus development. It was found to be optimal at 28°C and was promoted by through soaking of the graft components and maintaining a high humidity at the graft position. Cell division in the cambial zone began below the wound surface after 5-8 days at 28°C. Growth regulators based on chlorobenzoic acid promoted callus formation. Direct application of fungicides to the cut surfaces can delay callus formation. Under certain circumstances a corky layer formed between the 2 calli at the graft and prevented fusion. This was the chief cause of grafting losses in grapevines.

Treatment with Dropp (Thidiazuron 50% W.P.) stimulated callusing and union formation in graft component at lower concentration than stand and compounds IAA, IBA and NAA. The acitivity of the synthetic cytokinin in contrast to that of the 3 auxins was not adversely affected by temperature reduction indicating the possibility of simplifying the process of graft stratification.

In an experiment with RepariaxRupestris 104-14 cuttings, treatment in 0.005 or 0.01% solution of mesoinosit (a plant derived substance with vitamin activity) produced higher percentage of standard graft compared with auxin application and under control.

Grapevine bench grafts at various stages (from newly grafted to those with leaves) were dipped in 10 commercial waxes. The temperature of the wax was important to help penetration, 75-80°C being suitable, but plunging the waxed grafts into water at 18°C for cooling was also necessary. Dipping grafts once in wax resulted in their retaining 55-65 per cent moisture content after 30 days compared with 45 per cent in the controls, but dipping twice resulted in a desirable 78 to 95% water content.

Stratification

Mishurenko and Presler suggested 24-26°C as optimum temperature for stratification of the grafted plants, and for basal portion of the rootstock the optimum temperature was 14.16°C. Mishurenko reported that high temperature of 25 to 30°C, though most favourable for graft-union, caused callus formation on the base of the rootstock and inhibited rooting. So he suggested to stratify in such a manner that the temperature around the union was maintained at 24 to 26°C and at the base at 14 to 18°C, which was earlier reported by him in 1951. A new method of rooting of grafted grape stocks was suggested by Boulay in which grafted stocks were put into compost, inserted in perforated cardboard strips and packed upright in a box which was heated from the bottom to allow gradual root-formation. Grafts were progressively acclimatized to external condition and they were planted in early July. Whip and tongue-grafted cuttings, when planted at an angle of 45° in well-manured sandy soil (preferably pure sand) in September-October, showed 55 to 75 per cent success while the classic method of forcing grafted cuttings in boxes with heat was not found satisfactory in Mendoza.

Breider observed that the success in vine-grafting depended largely on a favourable wood/pith ratio in the rootstock and the scion and this could easily be determined with the help of radiographs. A study was made on the graft-union of the cultivars Prokupac, Teleki 8B and BxR Kober 5BB stratified in sawdust, sand and moss. The highest percentage of good unions with rootstocks was obtained when the grafts were stratified in sawdust and the lowest when stratified in moss. Mitovic achieved a high degree of success in grafting and rooting by maintaining the temperature at 25 to 30°C during stratification, and 22-26°C and 18 to 20°C, respectively before and during the union. Stover reported 50 per cent take when the cleft grafts were covered with damp sphagnum moss and polythene. Mishurenko's method by which the union of the scion and the rootstock kept at 26-28°C and the base of the rootstock at 6-10°C, produced a much higher percentage of planting material than by the usual method of forcing vine grafts at an overall temperature of 24-25°C (Banita, 1958). Prolonged stratification, though favourable for callusing, caused premature root formation in the stratification box and more vigorous shooting of the scion.

Gricaenko described that upper section of the stratification box or container (55×45×60 cm) was reinforced with laths, 2 cm wide, through which wooden strips were slotted to keep the grafts level. The top was packed with pine sawdust. A layer of fine sand above the heating element was located in the upper section, about 3 cm below the area of the graft union and 8.8 cm from the top of the grafts. The electrodes consisted of 2 sheets of iron 4×35 cm large and 50 cm apart, which were 5 cm from the walls of the container in a layer of sand. The temperature was 28-31°C near the electrodes but only 21-22°C elsewhere in the container. Nikolenco described a metal container in which 600-650 grafted vines may be stratified at a controlled temperature between 18 and 30°C and in a controlled humidity between 60-100% RH. For the first 2-4 days of stratification the humidity was maintained at the maximum, being reduced by 1-2% every 2-3 days thereafter. After 9-11 days, a callus layer formed, and after 12-14 days the humidity was reduced to 65-70% when the callus became covered with a layer of brown dead cells. After 16-18 days, temperature and humidity were progressively lowered until the grafted vines were planted out on the 32nd day. The union of plants stratified in the new container was stronger than after normal stratification. Vine grafts stratified in old sawdust which had been used in the previous year were more vigorous than grafts stratified in new sawdust, and suffered less from mould. Covering the upper half or the whole plant gave the best results. During 4 years studies with 4 vine cultivars grafted on Riparia × Rupestris 101-14 rootstocks, stratification in callusing boxes in cool rooms at 23°C for 20 days resulted in callusing up to 93.2% of vine scions and up to 100% of rootstocks compared with 86.6% and 80%, respectively, obtained by conventional stratification in hot houses at 26°C. The optimum temperature for successful take was 20°C maintained for 19-22 days in the graft union area and 15°C at the base, and this resulted in 74.3% first grade grafts compared with 34.3% obtained from the control kept at 26°C. Callusing and union were improved when the upper ends of the grafts were warmed at 20-23 °C for 18-22 days by packing them upright in boxes and covering with damp sawdust containing the electric element. Of the methods tried to prevent drying out, paraffining the tips or covering the leaves with polythene gave good results. Grafts stratified in early April showed a lower carbohydrate content and produced fewer first grade plants than those stratified in late April. Stratification of the upper part of the cuttings for 12 days (at 18-20°C) for the first 8 days increased the number of well-callused grafts in cultivars Krasavitsa Tsegleda and Italia from 28 and 36 to 68 and 70 per cent, respectively. Polythene bags (0.1 mm gauge) proved to be a good material for the storage of grafted vines as compared to sand or leaf covering.

Maltabar and Zhdamarova obtained a higher number of first grade grafts with water stratification compared to sawdust. Grafting was carried out from late May to late June, and it was observed that the lower the scion was grafted on the rootstock the better was the take, but the recommended height was 0.5 to 1.0 m to avoid subsequent mechanical damage. The effect of standard grafting stratification and rooting, and grafted cuttings coated with paraffin from the scion apex to about 2-3 cm below the graft union prior to placing in boxes for strtification was compared. In autumn the first treatment produced 50.03% first grade grafts, and the second 55.93%. The mean percentage of

basic roots in the first treatment was 5.32 compared to 6.86 in the second and the annual weight increments were 11.52 and 13.15 g/vine, respectively. Tikhvinskii and others suggested stratification of the distal ends of Riparia × Rupestris 101-14 rootstock cuttings at 24°C for 7 days before grafting. After grafting the number of grafts with a round callus (at graft union) on the rootstock component was 3 times greater with treated than with unstratified control rootstock cuttings. The treatment also increased the production of first class transplants from 41.6 to 58.3%. In another trial with heat treatment and/or soaking in IAA at 0.005% for 48 hours or at 0.01%, the highest number of good grafts (63.4%) (compared to 44.8% in the control) was obtained when rootstock cuttings were heat treated and soaked in IAA at 0.01% prior to grafting. Vine scion cultivars Carbernet Sauvignon and Coarna Neagra grafted on Riparia × Rupestris 161-14 rootstocks were graded after stratification and hardening into first grade (with round callus and new growth) and into second grade (with round callus but without any growth). The second grade grafts were placed in water containing various nutrients where they remained for 5-6 days at 28-30°C and 96 to 98 per cent relative humidity. This treatment increased the production of first grade plants by up to 25 per cent. Studies were carried out on cultivar Sauvignon grafted on Riparia × Rupestris 101-14. The grafts were stratified at (i) 26°C ambient temperature, (ii) 22 or 30°C localized temperature (control), (iii) 22-26-30°C for 7 days at each temperature, (iv). 30-26-22°C as in (iii) and (v) 22-26-22°C as in (iv). The best results for the production of planting material and percentage of first grade transplants were obtained in (v) followed by (iv) and (iii) . Scion vine cultivars Rodina and Russkii Konkord grafted on the rootstock cv. Alfa were stratified at 5 different temperature regimes. The highest production of first grade planting material was obtained from grafts stratified at 28-30°C for 2-3 days then at 24-26°C for 5 days followed by 10-12 days at 20-22°C. High temperatures (28-30°C) throughout the stratification period resulted in very low production.

Naidina and Bukatar recorded the highest production or rooted grafts in cv. Coarna Neagra grafted on Riparia × Rupestris 101-14 rootstocks stratified with nutrient solution. In studies with the grapevine cultivars Galan and Cardinal, the grafts were stratified in water at 28 to 30°C or in sawdust with electrical heating. Production of good grafts in sawdust was 74.3 and 78.3 per cent and in water 88.8 and 91.4 per cent, respectively for Cardinal and Galan. However, grafts stratified in sawdust showed better root production during the later stages of development. Grapevine grafts were raised in nutrient solution on a sand substrate, maintained at various temperatures and it was observed that optimum substrate temperature was 25°C in which the production of first class transplants was 25.9 per cent higher than that without substrate warming. In trials with the grapevine cv. Aligote, grafts were stratified in water (control) or solution containing cysteine or gallic acid each at 0.003%. Percentage of grafts with a round callus under control and in cysteine and gallic acid-treated grafts were 64.3, 92.0 and 93.0, respectively.

Three year trials showed that amino acids activated respiration and pigment synthesis in the early stages of graft development and that this resulted in improved callus and root formation, and plant growth and development. Suitable treatments for grafts before stratification included 0.03% methionine, alanine, cysteine or leucine, or stratification in solutions of these amino acids.

Callus formation on scion and rootstock cuttings was studied during stratification in December or January in moist sawdust at 28°C. In December or January, scions of Muller Thurgau and Rhine Riesling produced callus issue earlier (by 5 days) than the rootstocks Kober 5BB and Oppenheim S04, but later in the season these differences almost disappeared. The start and capacity of callus formation on the cuttings were determined by the stratification date and their genetic provenance.

In another experiment on cuttings (prepared as graft wood) of the scion cultivars (*V. vinifera)* Rheinriesling and Muller Thurgau and the rootstock cv. (*V. berlandierixV. riparia)* Kober 5BB were stratified in damp sawdust at 28°C for up to 25 days in winter. Callus development was more rapid on scion cuttings placed horizontally rather than vertically. The rootstock cuttings also showed better callusing when placed horizontally but produced a lower percentage of cuttings with callus than the scion material.

Gogebashvili and Bulakh reported that stratification after irradiation with gamma rays increased endogenous ABA and decreased endogenous IAA in Riparia × Rupestris 104-14 rootstock cuttings compared with stratification only. They suggested that irradiation could be used to improve grafting success by synchronizing initial dormancy breaking and callusing.

Use of Paraffin

Henriot reported that vine grafts when waxed with paraffin and kept in warm frame showed better results than the untreated ones. The necessity of paraffin waxing to protect the graft from desiccation was also emphasized by Cornu. Vidal and Roche reported that scions of different cultivars, when cleft or mortise-grafted on rooted plants of R99 and the grafted plants were dipped to 3-4 cm below the cuts in commercial paraffin wax (M. P. 52-55°C) at about 70°C, showed 82 to 91 and 76 to 90 per cent success, respectively, in the two methods of grafting. The earlier observation of paraffin waxing by Roche was also supported by Carlone with a good degree of success, and he concluded that the paraffin should be free from unsaturated hydrocarbons, and that addition of a plasticizing agent, such as polyisobutylene was an advantage. A more successful union of graft components was obtained by coating the grafting area with a thin film of paraffin wax before stratification and again before planting out. The upper end of the graft was immersed to 3-5 cm below the union in melted paraffin at 65-75°C for not longer than 0.5 to 1 second. The grafts were planted out with the union 15-20 cm above the soil surface, and were later earthed up to 3-5 cm below the graft union. After 2-4 days, the tip and leaves of the paraffined shoots turned yellow and eventually died, but axillary buds on the new shoot or dormant basal buds developed later. The number of transplants obtained from this treatment was 10-25% higher than that from untreated grafts . Different methods of paraffin treatment were applied to vine grafts instead of earthing up in the nursery. Paraffining at the time of grafting produced fewer good quality grafts than paraffining at the time of planting in the nursery. However, the protection of the graft union with PVC tubes or rubber bands. Paraffining at the time of grafting and planting out after stratification gave significantly better results than paraffining at the time of planting. Paraffining at 70 and 80°C gave poor results on the production of first quality graft. Only in the case of paraffining at 80°C, followed immediately by cooling in cold water, were the results as good as those without treatment. Double paraffining at 60°C also gave poor results. The most favourable time for paraffining stratified grafts was when the callus ring was forming at the union. Dipping vine grafts rapidly into melted paraffin at 68-70°C to coat the scion, the union and 6-8 cm of the rootstock obviated the need for earthing up and resulted in the development of stronger plants on which the wood ripened better.

In the trials, using the cultivars Pearl de Csaba and Perlette on Craciunel-2 rootstocks, comparisons were made between 2 soil temperature ranges (10°-12°C and 12°-14°C), 3 types of graft cover and 3 arrangements of the plastic cover (covers as a tunnel or along the sides of ridges) for unstratified vine grafts. A stable soil temperature in the range of 12°-14°C proved the best and a paraffin wax coating for the graft was better than the other types for cover under these conditions and with the ridges protected by plastic sheeting, a take of 52.67-56.36% was obtained. Several types of commercially available paraffin with various additives were tested for their protective use on vine grafts. The best results were obtained with a mixture of paraffin+3% rosin+3% bitumen+0.15% Benlate (benomyl). Grafting success was 12.5% greater with these substances than with pure paraffin (Grecu and Stoin, 1972). Podgornyi reported that union of the first grade grafts when immersed in paraffin at 80°C and stored in 5 cm of water showed 65.3 per cent success while a second immersion in paraffin before planting gave 82.5 per cent success. He also claimed that planting of twice-immersed grafts was more economical than the conventional method of planting and earthening up. Several methods of inducing rooting in grafts of Italian Riesling on Chasselas × Berlandieri 41B were evaluated by Lilov and Draganov in comparison with stratification. Of these methods, only covering the grafts with 7-8 cm of damp soil, and treating them with paraffin after grafting but before rooting were satisfactory, giving 69.06 and 72.06% first quality transplants,

respectively. Stratification gave 79.60% first quality transplants but the above 2 methods were considerably less expensive. The conventional treatment of vine grafts, after stratification and before planting with paraffing wax at 90-95°C frequently caused scalding of new growth, and callus growth was also found to be inhibited. Aron *et al.*, therefore, suggested to dip the grafts in a tank filled with water (maintained at a temperature sufficiently high to keep the wax liquid) and topped with a 1-2 mm thick layer of paraffin wax to avoid injury. In trials with the vine cv. Hindogni on Kober 5BB rootstock, Todorov *et al.* recorded 59 per cent success by planting without earthing up; 47 per cent by treatment with paraffin wax and earthing up; 53 per cent with a mixture of 97 per cent paraffin wax and 3 per cent bitumen, without earthing up, while 50 per cent in case of treatment with 94 per cent paraffin wax plus 3 per cent bitumen and 3 per cent colophony.

Ozocerite formed a better protective layer on vine grafts than paraffin wax and this resulted in better graft survival in the nursery. A mixture of ozocerite and paraffin (2 : 1) was also beneficial and gave 10% increase in the production of first grade transplants compared with untreated controls. Bench-grafted grapevines treated with paraffin wax and planted out during very warm weather (30-34°C) suffered heavy losses due to the blocking of tracheid of the xylem and soft tissues of the phloem. Grecu *et al.* concluded from the results of the experiments that wax comprising 94% paraffin, 3% colophony, 3% bitumen and Benlate (benomyl) at 0.15% was the best.

Other Factors Influencing Graft Union

Vine grafts planted at 40-45° angle up to a depth of 20-25 cm rooted better than those planted vertically up to 35-40 cm depth, because the upper soils were rich and warmer for good growth of the roots.

Banita and Baltagi observed that rootstocks 8-9 mm in diameter and the scion of the same size were best for grafting and the highest percentage of grafted plants was found from cuttings of the middle section of the shoot, compared to those taken from the base. Moreira *et al.* in an experiment noted high percentage of take with rootstocks of 30-40 cm in length, which was quite as good as those from the traditional low grafting. Horanszky recorded the possibility of mechanization of vine shoot grading according to diameter and concluded that shoots of 6-10 mm in diameter were suitable for either hand or machine grafting. Shoots of 10-12 mm should be hand grafted and those below 6 and above 12 mm in diameter should be discarded as these were not suitable for both hand and machine grafting.

It was found that shoots from different parts of the mother plant were different in respect of the catalase activity and the contents of chlorophyll and carbohydrate in their leaves. The shoots which gave the highest percentage of first quality transplants were those taken from the replacement branches and from the middle section of the fruiting wood.

It was observed that the use of a basal scion considerably improved rooting and shoot growth, resulting in an increase of 7 per cent in the number of first class plants. Suppression of the bud on the basal scions was found to increase the shoot growth a little further and significantly reduced rooting from the basal scion and slightly increased that from the rootstock.

Romberger *et al.* studied the influence of two callusing methods on the success of bench-grafting in *Vitis vinifera*. The treatments were covering or non-covering (during the callusing period) of the graft-union with dry sawdust and of the scions with a wet peat-vermiculite-sand mixture. The non-covering treatment produced a significantly higher percentage of total yield. It was also found that sap exudation from the top of the scion on the following day indicated a good take.

Barabal Chuk and Dranovskii observed good callusing and subsequent shoot development on grafts by water treatment at 46 to 48°C for 10 minutes, and the best rooting at 30°C for 40 hours.

Bud-slips from well-developed non-lignified scion shoots showed the maximum success when the grafting was done in the month of May.

Shugin reported that reversing the conventional procedure and soaking the scion in water after they had been shaped produced good results in grafting.

Grapevines cv. Alicante Bouschet on Rupestris du Lot (planted in 1970) were topworked (using T-grafting) with cv. Cabernet Sauvignon between 25 May and 13 June. The scions (with 2 buds each) were collected in February and held in plastic bags at 5°C until required. Topping immediately before top-working gave the best take (about 93%). Without topping, scion growth was poor. In another trial, grapevine cv. Servan on 99R were topped 50 cm above ground and cleft grafted with two Chardonnay scions between 28 April and 18 May. The take was 71.9%. These vines were not as vigorous as Alicante Bouschet.

Polyak *et al.* reported that from year to year the percentage of rooted grafts originating from an SO_4 nursery was less than that originating from a 5C nursery. The two rootstocks showed differences in callusing capacity and also in K content of the leaves (1.1-1.4 and 0.6-1.0% for SO_4 and 5C, respectively). To determine whether nutrient content affected callusing capacity, cuttings of both rootstocks were grown in pots and supplied with nutrient solutions of different compositions. Nutrient uptake was essentially determined by the N, P and K contents of the solution. An increase in the N, P and K concentrations of the solution and the N, P and K contents of the plants, reduced the callusing capacity of the canes, an increase in K concentration having the greatest effect. The reduction in callusing capacity with increasing nutrient concentrations was greater in SO_4 than in 5C canes. High leaf and cane K contents were associated with low Ca and Mg contents. The highest carbohydrate contents and callusing capacities were recorded in canes of both rootstocks having K contents of 0.3-0.5%.

Treatment of grafts before stratification with a microelement complex (Ni, Cr, Mn and Ti) at 10^{-3} M improved callus formation at the vascular union, growth, yield and quality in all rootstock scion combinations used.

Irradiation of cuttings of RipariaxRupestris 104-14 with gamma rays inhibited bud-burst and increased production of standard grafted material by 7.8-11.2% compared with untreated control.

Storage of Graft

Becker suggested that the rootstock and scions should be treated with a solution of 5% Chinosol for at least half an hour before storage and again for up to 12 hours before grafting to prevent infection by *Botrytis*. Callusing boxes should be treated with 0.1% Chinosol. A paraffin preparation containing substances toxic to *Botrytis* had been developed for use on bench-grafts. Scions of Portugieser blau vines were soaked for 30 minutes in 0.5% Chinosol and then budded onto 125AA rootstocks. Those taken from mother plants with severe dead-arm infection failed to take, and by the early summer many of the vines died. Scions taken from healthy mother plants were not infected.

The results of trials on storage, disinfection and paraffin treatments of vine grafting material were reported by Gartner. Grafts stored best in a cellar in sealed polythene bags. Outdoor storage in clumps resulted in the greatest losses, and storage in cooling chambers had no advantage. Covering the material with sand led to higher moisture losses than storage in polythene bags. Both Chinosol W and liquid Albisal gave good control of grey mould *(Botrytis cinerea)*, but addition of compound liquid fertilizer Wuxal to Albisal increased rooting.

Grafted vines were stored for 1 year at 0°C and 90% RH and packed in three ways. The best results were obtained when they were packed wet in closed 0.1 mm gauge polythene bags. Losses were greater when the vines were covered with sand or left uncovered during storage. After a pre-storage treatment against *Botrytis* with Chinosol, vines in bags showed little or no fungal attack. No water loss was observed in the bagged vines. Their stored carbohydrates, particularly those in the roots, were metabolised but were not depleted. Laszlo and Valeanu found that scion and rootstock material stored at 0°C showed better subsequent growth compared to that stored by means of polythene wrapping or in sand indoors.

Experiments showed that grafted vines could be kept for long periods in cold storage, if they were treated with fungicides and enclosed in plastic bags impervious to water vapour and if their respiration was reduced to a minimum.

Becker and Hiller in an experiment found that treatment of grafting material with a Chinosol solution controlled *Botrytis cinerea, Phomopsis viticola* and other fungus infections and significantly increased the successful take and rooting of vine grafts. The most effective pre-storage treatment was soaking of the grafting material in 0.5% solution for 15 hours at 10-18°C. The material was then stored in plastic sacks. To control spotted necrosis *(Rhacodiella vitis)* during storage, the rootstock and scion shoots of 2 grapevine cultivars were immersed in 0.5% Chinosol solution for a few hours and stored in sawdust for 3-4 months before grafting. With scion cv. Odesskii Rannii and Riparia × Rupestris 101-14 rootstock, immersing for 3 hours gave the highest number (58.2%) of transplants after grafting. In Aligote and the same rootstock, immersing the rootstock and scion cuttings for 3-10 hours, then storing and re-immersing the scion cuttings for 12 hours and rootstock cutting for 24 hours before grafting gave the highest number (36.7%) of surviving first grade transplants in the nursery.

In a study with grapevine, Uchoa found that cv. Nebbiolo scions cut in November, February or March, storage in polyethylene bags at 4°C and stratification in sand in the open, both kept the material suitably moist, limiting moisture loss to 1.7% but the cold treatment was necessary for rapid shoot development. A study of bench grafts, after forcing, showed that neither the development of shoots on the scion, nor wound callus development provided a good index of final union development in the nursery. Union development was most successful in bench grafts incorporating scion material which had been stored at 4°C. The final yield of grafted and rooted material was greatest where scions were cut in March just before grafting.

Biochemical changes

In the spring, Gymza and Mavrud vines grafted on Monticola and Kober 5BB rootstocks had higher total amino- and protein nitrogen percentages in the sap, and throughout the growing season higher peroxidase and polyphenol oxidase activities and a higher pigment content in the leaves than plants of the same cultivars growing on their own roots. It was concluded that in the root system of vines important biochemical processes occur, which are closely related to the oxidation processes and the accumulation of pigments in the aerial organs.

Cuttings of vine rootstocks treated with 0.2% hydroquinone, 0.1% potassium bromide or 0.01% heteroauxin were grafted and then stratified. Chromatographic analysis at the end of the stratification period showed that the growth stimulants increased the supply of sugars and amino acids in the cuttings. The action of these three subtances on both qualitative and quantative supply of sugars and amino acids was specific.

Both the number and amount of free amino acids increased in vine cuttings during stratification until the time when callus and rootlet formation became intensive, thereafter the amino acid concentration began to decline. Four sugars were present in large amounts in the cuttings at the start of stratification but the amount of sugars gradually declined during stratification. The callus contained only small quantities of glucose.

In a study of several combinations of 3 scion and 3 rootstock cultivars, samples from the graft union of the incompatible pairs showed significant changes in pH and isoelectric point in the cells of both components. Changes in compatible pairs were very slight. The polyphenolixidase and peroxidase contents were higher in the incompatible than in the compatible combinations.

Acid and alkaline phosphatases, peroxidase and esterase of 5 cultivars (Airen, Grenache, Tempranilla, Bobal and Maccabeo) and 6 rootstocks (420A, 41B, 99R, 110R, 161-49C and 196-17CL) were subjected to polyacrylamide gel electrophoresis. Masa suggested that acid and alkaline phosphatases were the most useful for determining scion-rootstock affinity based on izoenzyme similarity. Results were in agreement with those previously obtained with protein determinations.

Grapevine (cv. Cabernet Sauvignon) scions were hand or machine-grafted on Berlandieri × Riparia or Kober 5BB rootstocks and stratified and hardended by the standard method. When IAA content was determined immediately after stratification and 30 and 60 days after rooting, no differences were found between treatments. It is thought unlikely that the poor quality of some machine-grafted material is associated with auxin content.

Top Working

In an investigation on top working in Greece, Stavrakas reported that the grafting date did not affect take when bark slipped well. Take was, however, affected by rootstock-scion combination. Athiri on Limmio/IIOR giving the highest success rate (93.6%). T-budding was more successful (> 90%) than cleft grafting at ground level (64.68%), the traditional method for top working a vineyard.

BUDDING

Methods

T-budding on resistant rootstock with the stock-scion union well above soil proved valuable for establishing vineyards. Treatment of the budwood in paraffin emulsion increased the efficiency of budding (Anon., 1941-42). Poor take was observed in cuttings from lateral shoots, shoots derived from dormant buds and those with the 3rd and the 4th bud from the base of the shoot.

The grapevine cv. Aligote was budded in the nursery onto the phylloxera resistant rootstock cv. Riparia × Rupestris 101-14 at 30, 60, 90 or 120 cm above the ground. The final production of budded material in the nursery was 33,500/ ha of vines budded 60 cm above ground compared with 28,900/ha in the control budded just above ground level and 25,900/ha of vines budded 120 cm above ground. High budding reduced labour by 8-10% compared with the control. Very good success was obtained with side budding of softwood as well as hardwood bud shields and with cleft budding of hardwood bud shields. To prevent drying in the summer heat, waxing of grafts was recommended. In the modified technique reported by Alley the lower cut on the bud shield as well as the corresponding cut on the rootstock was made at an angle of 25-30° and the bud shield was tied with $^1/_2$ inch white plastic budding tape. In a trial in which budding Cabernet Sauvignon onto St. George rootstocks by the standard method had failed, rebudding by the modified method resulted in 80% bud take.

Alley recommended chip-budding for changing one cultivar to another on mature vines, because it required relatively little skill and gave a satisfactory take. The best take of one-bud cuttings was obtained when they were taken from the 5th to the 20th bud along the cane. Chip-budded vines gave a bud-take as successful as T-budded vines and control of budding did vot affect the take of chip-bedded vines, but affected the take of T-budded vines (Alley and Koyame, 1980). In another experiment, Alley and Baron reported that in case of T-budding, the standard and the inverted type bud-cuts gave equal bud-take when budding was controlled, but the standard bud resulted in earlier bud-break.

Boubals described a technique of chip budding and suggested that when two scions were inserted opposite each other at the end of March or in April, the take was about 90%. However, failures may be grafted by the inverted T-method at flowering and overall take may reach 99%.

Maltabar and Radchevskii budded shield buds of the promising scion cultivars in June on the Moldovan rootstock type V-52-16 (using hardwood shield buds) or on cv. Yubileinyi Magaracha (using softwood shield buds). After budding 1, 2, 3 or 4 leaves were left on the rootstock component above the budding union to assist good take. In addition, the rootstock component was cut back above the budding union either on the day of budding or 3, 6, 8, 12 or 15 days after budding. The best budding success (94.1-94.4%) was obtained by retaining 2 leaves above the union and cutting back 6 days after budding.

Effect of Season

In a vine budding trial, using a special shape of chip-bud, scions of Perlette and Pearl de Csaba were grafted onto Anab-e-Shahi, Gulabi and Kandhari rootstocks in the rainy season (August) and winter (January). Attempts with the cv. Perlette were almost unsuccessful. Pearl de Csaba was budded on Gulabi and Anab-e-Shahi rootstocks with success rates in the range of 20-30%. No success was achieved with Pearl de Csaba on Kandhari. Winter budding was both easier and more successful than August budding.

Budwood was collected in December and stored at 0°-1.5°C until June, and fruiting vines were decapitated about 90 cm above ground. T-buds inserted 2-3 cm or 10-15 cm below the cut ends gave 90% take, the growth of the former being better.

In order to obtain transplants with a frost-resistant stem, shield-buds of the scion cv. Aligote were grafted on 1.5-1.6 m canes of CO_4 rootstock. Grafting was carried out between late June and mid-August. Production of standard planting material was 50 per cent with summer grafting, but only 23 per cent with bench-grafting.

In an investigation with cv. Thompson Seedless chip-budded to Chenin Blanc, it was observed that during March chip-budding was more successful than T-budding. Chip-budding in April was found as successful as T-budding in June, but the take of chip-budding in March was lower.

Effect of Rootstock

Muscat and Bangalore Blue scions were chip-budded on unrooted Anab-e-Shahi cuttings and Anab-e-Shahi scions on Bangalore Blue and planted in sand, vermiculite, sphagnum moss in pots or in moss in polythene covers. Muscat on Anab-e-Shahi planted in sand gave the maximum take of 85 per cent. Bangalore Blue and Anab-e-Shahi combination did the best in moss and polythene (70%). Muscat scions on Anab-e-Shahi rootstock (whip grafting) showed 10 per cent success in sand and 5 per cent in vermiculite.

Stocks of 16 cultivars of grapes were pruned to one shoot of the current season's growth, 30 cm long; these were then shield-budded on virus-indicator cultivars St. George, Mission or LN

33. The establishment was over 80 per cent for all the 3 rootstock cultivars.

Storage of Bud

Dormant bud shields cut from cultivars Emperatriz and Riesling were successfully cold stored until the spring. Three thousand shields were stored in the same space required to store approximately 100 cuttings that would yield about 500 bud shields. When T-budded, the percentage of take following sand storage was 97 for bud shields and 98 for cuttings.

Effect of Methods of Propagation

In a trial with Red Niagara *(Vitis labrusca V vinifera)* on RipariaXRupetris 101-14 rootstocks the types of planting material and the total grape yield per 120 vines in the first 4 years of commercial production were (i) grafted plants 387 kg, (ii) rooted cuttings for grafting the following year 589 kg and (iii) unrooted cuttings for grafting after rooting 534 kg. The cv. Pusa Seedless was chip-budded on Anab-e-Shahi rootstock with 65 per cent success and on Bangalore Blue with a success rate of 40 per cent. However, whip grafting was a failure on Anab-e-Shahi and only 25 per cent successful on Bangalore Blue. The length of shoot produced by the graft greatly exceeded that of the shoots produced by the buds after 90 days. The activity of reducing enzymes, photosynthetic productivity and the accumulation of carbohydrate were more intensive in vines propagated by grafting than by cuttings. Side-budded plants were more vigorous than those bench or saddle grafted. In a trial, 50-year-old Moscatel Rosado gapevines were cleft-grafted with 2 scions each of Pinot Gris and observed for 18 years. The method proved successful but only 1 graft took in 15.5% of the plants, with a resulting loss in yield. In a second trial, 7-year-old Criolla Grande grapevines trained on a 2 branch espalier system were grafted with either cv. Cardinal or Italia, by one of the following methods (i) flute budding with a growing or dormant bud, (ii) bud-grafting with 4 scions/rootstock, 2 on the trunk and 1 on each branch, (iii) cleft-grafting with 2 scions/rootstock below soil level and (iv) T-bud grafting with 4 scions/rootstock, 2 on the trunk and 1 on each branch. There

were no significant differences in take between methods, but after 3 years method (iii) led to significantly higher fruit yields and wood production than the others. This was attributed to scion rooting. Fruit yeilds followed in descending order (ii), (i), (iv). Method (iv) led to tissue proliferation at the union and therefore to scion loosening. No differences were noted due to scion cultivar or to the use of growing or dormant buds. Dass and Melanta in their studies on whip grafting, splice grafting and chip budding made in the month of April and October reported that chip budding gave better results than whip grafting. In October, splice grafting proved effective compared to chip budding for the cultivars Gulabi and Cheema Sahebi on rootstocks of Bangalore Blue and Anab-e-Shahi, whereas in April there was a higher percentage of successful union from chip budding than from splice grafting of Anab-e-Shahi scions on Fakdi rootstocks.

Source of Scion

The flowering stage was found to be the best time for green wood grafting since at this time the cambium produces many undifferentiated cells which ensure rapid wound healing. This activity was greatest in the internodes 4 to 8. The success of green wood grafting was found to be closely related to the level of water reserves in the soil. In an experiment on cultivars Italian Riesling, Afuz-ali, Prokupac and Smederena, scion wood was obtained from plants not allowed to fruit, from plants allowed to fruit, from high-yielding plants and from low-yielding plants. The grafts showed a higher percentage take and made better growth when the scion were taken from low-yielding than from high-yielding plants. On the other hand, the scions from the plants allowed to fruit resulted in better grafts than those from plants prevented from fruiting.

Rootstock

Adaptability of Soil and Climate

One-year rooted stocks were bench-grafting in the spring of 1941, grown in the nursery a year and planted out in 1915. Of the cultivars tried, Catawba, Niagara and Delaware did best on

Clinton and the gain in quantity and quality of fruit was highly profitable. Lona was particularly well suited on Rupestris St. George and on Clinton. Concord on gravelly loam did best on Riparia Gloire, while on silt loam working on Clinton tremendously increased the fruit production. The vine rootstock Chasselas × Berlandieri 41B was found to withstand a large amount of carbonate of lime without its scion being chlorotic. In summarising the performance of rootstocks Emon classsfied Riparia as a stock for rich deep soils. Rupestris, the most widely used stock, should be raplaced in dry soils by 44-53, a Cordifoliax Rupestris hybrid, by 150-15, an Aramon × Rupestris × Berlandieri hybrid or by Rupestris × Berlandeiri hybrid e.g., 99 and 110. In addition, 196-17, a 1203 × Riparia-Gloire hybrid, was more vigorous than Rupestris. The Riparia × Berlandieri hybrids 420A and 161-49, were recommended as the most suitable stocks for agrillo-silliceous and calcareous-silliceous soils, while the Rupestris × Berlandieri hybrids 99 and 110, the Aramon × Rupestris × Berlandieri hybrid 150-15, the Franco × Rupestris × Berlandieri hybrid 150-15, the Franco × Berlandieri hybrid 33 and the Colomba × Berlandieri hybrids were preferred on calcareous soils. Harmon reported that rootstocks of Rupestris St. George, Dogridge, Constantia, Mourvedre × Rupestris Nl 202 and Monticola × Rupestris could be suitably used for grafting in the Napa valley regions of California. Attempts were made at East Lansing to render the desirable Campbell grapes less exacting in its soil requirements by grafting it on certain vigorous rootstocks. On a soil of medium fertility all grafted plants produced a heavier crop than own-rooted vines of the cultivar. Riparia × Rupestris 3306 was superior to all other stocks. Vines on their own roots showed resistance to drought than did grafted Chasselas.

Of the rootstocks used, 125AA was most affected by frost, while 8B and 5C suffered the least. In an experiment at Novocerkank, Rostov region, European vine cultivars grafted on a frost-resistant European-American and hybrid Bajtur rootstocks performed much better than those grown on their own roots. Soil moisture utilization, assimilation, transpiration, dry matter

accumulation and consequently growth and fruiting were better in the grafted vines. The performance of several American rootstocks grafted with Riesling × Sylvaner or Pinot noir had been observed in various parts of Switzerland. Berlandieri × Riparia 8B (Wadenswil selection) and in dry situations 5C gave good results in soil associated with chlorosis. It was observed that Chaselas × Berlandieri 41B was resistant to chlorosis while Berlandieri × Riparia 5BB was too vigorous for close planting. Vivona in an experiment, assessed the qualities of several rootstocks including various crosses of Berlandieri, Rupestris, Riparia and Aramon under Sicilian conditions. The roots of Rupestis du Lot rootstock penetrated deeply and made it particularly suitable for deep soils with a low water retaining capacity. It is resistant to lime-induced chlorosis and to soil chlorides and is compatible with many of the most fruitful cultivars. In trials durings 1969-73 with Sultana, clone H5 on 12 rootstocks, Salt Creek was the most satisfactory stock on light soils in the Mildura area. Dogridge, though inferior to Salt Creek, was better than the rest. Salt Creek, however, generally gave a yield increase of at least 50% where nematode effects appeared to be insignificant. In rootstock trials on sandy soils, Barlinka and Alphonse Lavalle grapevine cultivars on Salt Creek rootstock out-yielded several rootstocks, but Salba yielded best on Dogridge. In black alluvial soils, however, Barlinka and a new cross yielded best on 143B rootstock. Zhukov and Moskalenko reported that rootstocks, Riparia × Ripestris 101-14 and RipariaXRupestris 3309 were suitable for slightly calcareous soil, Craciunel-2, CO4 and Kober 5BB for moderately calcareous soil, ShaslaxBerlandieri 41B for highly calcareous soil and Solonis 1616 was found suitable for saline and wet soils.

In a 5-years trial on unirrigated land in the Lazio region, it was observed that the rootstocks did not affect the yield Cardinal grapevines. Grafting on Ruggieri 140 stocks showed a 2-3 days earlier ripening compared to grafted on 420A or Kober 5BB, while rootstock 420A retarded and prolonged ripening

One-year-old vines of 20 classical grapevine rootstocks and 7 new rootstock genotype were grown under a restricted water regime (1/9 maximum evapotranspiration) in small containers in the greenhouse. The parameter F/rs (F = total active leaf area; l/rs = stomatal conductance of active leaves) was used as a measure of drought resistance. *Vitis rupestris*X*V. berlandieri* rootstocks Richter R110 and Ruggeri R140 and *(V. cordifolia* X*V. rupestris)* X*V. -riparia* rootstock Malegue 44-53 were classified as highly resistant and 6 other rootstocks were resistant. It was concluded by Carbonneau that increased water absorbing activity of the rootlets was the primary mechanism of adaptation to drought. Faccioli *et al.* in their detailed study with cv. Sangiovese grafted on different rootstocks recorded increased yield on BerlandierixRiparia Selections SO_4 and 125AA. In shoot maturation studies, it was noted that the totals of 1200° to 1300° of active temperature (above 10°C) were needed for good shoot maturation and among the different rootstocks included in this study, rootstocks RR 104-14 (94.2%) BRCCO^4 (95.4%) and CB 41B (93.8%) were found to be superior.

In Arizona, USA, seven rootstocks were grown in soil columns irrigated with water at 3 levels of salinity : EC values of 0.45, 2.5 or 5.0 dSm^{-1}. Arbabzadeh and Dutt reported significant reduction of shoot growth, pruning weight, leaf area and trunk diameter by increasing salinity. Reductions in shoot growth and pruning weight were greater than those in leaf area or trunk diameter. Based on percentage reduction in growth, the relative tolerances of the rootstock were; Salt Creek and Kober 5BB > Oppenheim SO_4 and Couderc 1613 > Richter 110R and Barbera > Millardet et de Grasset 41B.

Grapevine cv. Tannat (clone 1215), grafted on Riparia-Rupestris 3309C (control) or 101-14, Berlandeiri-Riparia 420A, or Berlandieri-Rupestris 140, Ruggeri or 110R, were planted in 1965 on a stony (21% gravel) but very clayey (> 30% clay) soil. Berlandieri-Rupestris rootstocks gave yields similar to those of the control. Yields on Riparia-Ripestris 101-14 and Berlandieri-Riparia 420A were lower because of susceptibility to drought and poor drainage, respectively.

The introduction of new rootstocks, e.g. SO4 and of rootstocks for specific soil or climatic conditions, e.g, 140Ru, 1103P, 41B, has created a need for new mother vine training methods to ensure good hardening of the wood.

In Japan, rootstocks 3309, 5BB and HF showed inhibition of shoot growth at soil pH 5, while 5BB and HF showed more vigorous shoot growth at pH 6. The cv. Kyoho showed low drought injury symptoms on rootstock 101-14 but high on 110R and 5BB. The rootstock SO_4 was found flood tolerant for cv. Kyoho while for cv. Fujiminori, the rootstock, 101-14 and 5C were found tolerant to flood.

Disease and Nematode Resistant Rootstock

Gervais mentioned the influence of soil on vine rootstocks and on the actual effect which they had on their scions and on their resistance to phylloxera. He noted the more important characteristics of some of the Riparia, Rupestris, Cordifolia and Berlandieri hybrid rootstocks. Branas concluded that 'Court-none', a virus disease which was found to spread by phylloxera could only be minimized through effective sanitary measures. The effect of rootstocks was not so pronounced. Coulondre observed that scions on rootstock 1202 showed infection by rot-burn, but not those on Rupestris, and grafting vigorous scions taken from a cultivar resistant to phylloxera imparted vigour to the rootstock. Rip × Rup 3309 rootstock was resistent to phylloxera.

In Portugal, the yield of vines was reported to be comparatively low due to phylloxera infestation and dry, sandy nature of the soil. The use of phylloxera resistant rootstocks was suggested by Bessa Ribeiro and the rootstocks of Berlandieri and Rupestris species and hybrids were found resistant to drought and tolerant of lime. In another experiment, he suggested to use Corriola or Alves do Bairro as phylloxera resistant rootstocks for these regions. The triple-origin rootstock (Riparia-Rupestris-Cordifolia) which is highly resistant to drought, and probably to infections degeneration, was recommended for use in reestablishing vineyards seriously attacked by phylloxera on the non-calcareous soil of Attica. In Georgia, 3 local vine cultivars were crossed with the phylloxera resistant rootstocks, Riparia Gloire and Berlandier × Riparia. Out of 4,000 hybrid seedlings five were found to be more suitable as rootstocks than the widely used Berlandieri × Riparia 5BB . The rootstocks RipariaxRupestris 101-14 and Berlandieri × Riparia Kober 5BB showed good compatibility with the new downy mildew *(Plasmora viticola)* resistant cultivars. In an experiment on the resistance of own rooted and grafted vines to downy mildew, the use of the resistant cultivars Bajtur and Sejanec No. 46 as rootstocks increased the resistance of susceptible scion cultivars. Which were grafted on them. The susceptible cv. Arctic had the opposite effect when grafted with the same scion cultivar.

In an assessment of 30 rootstock varieties of vine, all showed good resistance to mildew *(Plasmopara viticola)*, while 5 of the NA hybrids and Berlandieri × Rupestris Pautsen 1103 were free of phylloxera *(Viteus vitifoliae)*. Production of cuttings was best in BerlandierixRiparia 504, Berlandieri × Rupestris Paulsen 1045 and NA 5147-50. The majority of rootstocks were compatible with Chasselas Dore, the best being Berlandieri × Riparia Graciunel 26, BerlandierixRiparia Cosmo 2 and Berlandieri × Riparia 504. Under artificial infestation using resistant *Vitis vinifera* cv. Ganzin 1 as a control, *V. rotundifolia*, *V. rupestris* cv. St. George, *V. champinii* cv. Salt Creek, 1613C, *V. riparia* and *V. arizonica* were classed as immune to *Daktulosphaira (Viteus) vitifoliae* type A. Rootstocks with no *V. vinifera* ancestry were either resistant or immune to type B, including Salt Creek and interspecific hybrids 5A, 5BB, SO4 and 3309C (all immune).

A 9-year study was made on the behaviour of Sultanina *(Vitis vinifera)* growing on its own roots and roots of Dogridge, Solonis × Othello No. 1613 and Rupestris St. George in a root-knot nematodes *(Meloidogyne* spp.) infested sandy loam soil in California. Fruit and pruning wood weight records indicated that Dogridge and 1613 were the two better rootstocks for this location. They were not significantly different in fruit production but Dogridge was significantly more vigorous.

The resistance of rootstocks to different populations of *Meloidogyne hapla* was recorded by Dalmasso and Cuani). They observed that 41B rootstock was susceptible followed by SO_4 and Riparia, while Rupestris and 99R were the least infested. Tampa rooted readily from dormant cuttings and in various grafting trials showed 88-100% successful unions. Scion vigour was greater on Tampa than on Dogridge, Lake Emerald or Blue Lake. Fruit yields of Fla/EII-46 scion averaged 4.2 kg/vine on Tampa compared with 3.3 kg on Dogridge and 3.7 kg on Lake Emerald. Tampa is resistant to Pierce's disease, anthracnose, downy mildew, and drought, and tolerant to *Meloidogyne* spp. and susceptible to *Isariopsis* leaf blight and grape leaf folders. Fercal rootstock (BCI No. 1, Berlandieri) which had been described as medium vigorous showed much resistance to Phylloxera and *Meloidogyne arenaria* and fairly resistant to *M. hapla*. It was also highly resistant to lime induced chlorosis. Goss and Cameron in an experiment with Zante Currant, Cabernet Sauvignon and Zinfandel grapevines grafted on several rootstocks in nematode infested soils reported higher yield on all the rootstocks than with their own roots. The best result however, was obtained with Ramsey and Dogridge. Fregoni reported that the new grapevine rootstock which was a cross between *Vitis berlandieri* × *Cabernet* Sauvignon and V. *berlandieri* × *Colombard* showed resistance to downy mildew, powdery mildew, anthracnose as well as phylloxera, *Meloidogym arenaria* and *M. hapla*.

Nematodes *(Meloidogyne* spp., *Tylenchulus semipenetrans* and *Pratylenchus)* are widespread in vineyards in the Murray Valley and Murrumbidgee Irrigation Areas. *Vitis vinifera* cv. Shiraz (an unindexed CSIRO selection) was grown on its own roots or grafted onto the following 6 rootstocks of varying nematode resistance. Ramsey and Dogridge *(V. champini)*, Teleki 5A *(V. berlandieri × V. riparia)*, Schwarzmann (F. *rjpariaxV. rupestris)*, Richter 110 (F. *berlandieri × V. rupestris)* and 1613 (F. *longii × V. labrusca × V. riparia × V. vinifera)*. Vines on rootstocks Ramsey and Dogridge outyielded ungrafted vines (mean yield 25 t/ha) by 46% and 48%, respectively, principally because of increased vegetative growth and therefore retention of more nodes at pruning. Nematode counts suggested that V. *champini* stocks have good tolerance to both root-knot and root lesion nematodes.

In an experiment on cultivar Carina grafted to the rootstocks Ramsey, Harmony, Schwarzmann, K51-32, 5BB Kober or Richter

110 were compared with vines on their own roots for resistance or tolerance to *T. semipenetrans*. Ramsey was the only rootstock resistant to the citrus nematode in the field. Low numbers of citrus nematode were found on or near the roots (254 larvae/500 g soil). Ramsey was also considered to be tolerant to the citrus nematode as Carina vines on Ramsey rootstocks had the highest yield over a 3-year period (30.7-38.8 kg fresh fruit vine^{-1} year^{-1}). While Harmony was not resistant, having large numbers of citrus nematodes on and about the roots (947-4919 larvae/500 gm soil), Carina vines on Harmony yielded well in this trial (25.0-28.3 kg fresh, fruit vine^{-1} year^{-1}), suggesting tolerance to the citrus nematode. All other rootstocks and own-rooted vines maintained similar levels of citrus nematode. However, grafted vines produced higher yields than vines on own roots. This could be due to tolerance to the citrus nematode or to rootstocks conferring greater root density or inherent vigour than own-rooted Carina grapevines. It is concluded that where citrus nematodes are known to be high, Ramsey rootstock gives the best yield and because of its resistance to the citrus nematode also.

Leguay and Bernard reported that Fercal, an INRA hybrid rootstock (*Vitis berlandieri* × *V. vinifera* cv. Colombard No. 1 × 333 EM) is very resistant to phylloxera (*Viteus vitifoliae*), fairly resistant of *Meloidogyne* nematodes and is the most resistant rootstock to chlorosis induced by calcareous soil.

In a review, Fraschini suggested that rootstocks apparently suitable for use on nematode-infested soils or for immediate replanting of vineyards were 39-16 (*Vitis vinifera* cv. Almeria × V. *rotundifolia*), 43-43 and 44.4 (both *V.vinifera* cv. Hunisia × V. *rotundifolia*), and 171-6 (V. *rufotomentosa* × *V. vinifera* cv. French Colombard).

Effect of Rootstock on Growth, Yield and Quality

Reynolds and Vaile found certain rootstocks increased the yield of the American grape cultivars Concord, Campbell Early and Moore Early as compared with the own-rooted vines, without affecting the quality of fruits.

It was reported that the largest area covered by vine on any particular rootstock was Rupestris du Lot, followed by B309C, 41B, Met G, 161-49C, Riparia Gloria, and that 37 other rootstocks were used.

No conspicuous failures or outstanding successes were noted on the fruit yield. From the results of experiments during 1937-1945, the standard stock Solonis × Othello No. 1613 was found as good as or better than the other.

In a trial at the Viticultural Experiment Station at Cours-les-Cosne on the effect of rootstock on yield, 4 hybrid direct producers and 3 *vinifera* cultivars were grafted on 4 different rootstocks. The hybrids out-yielded the viniferas on all rootstocks. The rootstock 161-49 gave the best yields with the hybrids, and 41B with the viniferas. The highest yielding scion cultivar was S. 7053 and the lowest S. 5455. In a trial with 21 hybrid direct producers on their own roots S.V. 18-315 was the highest yielding and one of the only 2 which produced acceptable wine. In a rootstock trial in the Napa Valley, California started in 1938, there was a trend, both as regards growth and yield in favour of the rootstock Rupestris St. George. The stocks Mourvedre × Rupestris No. 1202 and Dogridge had given results similar to each other but inferior to Rupestris St. George, while Solonis × Othello No. 1613 had given considerably poorer results. The performance of several American rootstocks grafted with Riesling × Sylvaı.er or Pinot noir was observed in various parts of Switzerland. Berlandieri × Riparia 8B, and in dry situations 5C, gave good results in soils associated with chlorosis. In general, Chasselas × Berlandieri 41B was resistant to chlorosis. Berlandieri × Riparia 5BB was too vigorous for close planting, and was not satisfactory with Pinot noir scions. In extensive trials in California, the experimental stock Aramon × Rupestris Ganzin 1 was the most vigorous and productive of those tested. Rupestris St. George, the most popular commercial stock was not considered the most suitable under the conditions of the test. Over a 5-year period, the yields of fruits and wine from Pinot noir were outstandingly higher on Sioux than on any other of the 16 rootstocks, and the wine was a higher alcoholic grade than those produced on 14 of these rootstocks. In a test of 8 vine rootstock cultivars at Meridian, Mississippi, where Pierce's disease virus limit the productive life of many cultivars, Barnes, Dogridge and B-45 were consistently effective in increasing the yield, vigour and longevity of the scion cultivars Concord, Delaware, Extra and Niagara. Results with DeGrasset, No. 161-49 and Vermorel rootstocks varied from the best to the poorest groups, depending upon the scion cultivars. Cynthiana and Herbemont rootstocks were poor.

In new Mexico, the *Vitis labrusca* cultivars Concord and Fredonia and the *V. vinifera* cultivars Thompson Seedless and Cardinal were each grown on their own roots and upon Solonis, Dogridge and Salt Creek rootstock. Fredonia was a more vigorous cultivar than Concord, but both were weak and chlorotic on their own roots. When grafted, however, both cultivars grew more vigorously and were not chlorotic, Salt Creek produced the most vigorous vines, and Solonis the least vigorous. Thomson Seedless and Cardinal were susceptible to winter injury, but own-rooted vines were less severely injured than grafted vines. Vines of these 2 cultivars grafted upon Dogridge and Salt Creek rootstocks produced more prunings than own-rooted ones and both rootstocks increased the vigour of Thompson Seedless . Rootstock-scion interactions and fertilizer levels on juice composition were studied by Ough *et al.* Analyes were made of juice of 10 vine cultivars grown on St. George and 99-R rootstocks receiving 2 levels of ammonium nitrate fertilizer. The differences in degrees brix, total N, ammonia, total acid, pH, tannin, K, biotin, phosphate and rate of fermentation were all significant, and greater for fruits on the St. George rootstock than for fruit on 99-R. The N fertilizer application significantly affected ammonia, total N and rate of fermentation values. The ammonia content showed a significant year × fertilizer interaction. The quality of the wine from clone 239 Geisenheim was influenced by the rootstocks tested, but this effect differed according to the site. No clear relationship between yield and wine quality was established with the rootstock-scion combinations tested. Oprea *et al.* in their experiment studied the growth, cropping, sugar content and acidity of 9 vine cultivars on 5 rootstocks over 3 years and assessed their relative

compatibility. The rootstock Teleki 1B was highly compatible with all 9 cultivars, and Riparia Gloire was highly compatible with 8 cultivars. The scion cv. Pinot noir was compatible with all 5 rootstocks.

In trials with different lengths of grafts, Deofasi and Kiraly observed that in case of Zinfandel on BerlandierixRiparia 5C rootstocks, 35 cm long grafts gave the highest yield. The sugar content was found to increase with decreasing rootstock length, while titratable acidity was highest in 40 cm long grafts and was the lowest when 35 cm grafts were used.

Speigel-Roy *et al.* studied the performance of the Queen of the Vineyards, Muscat of Hamburg and Dabouki on 8 different rootstocks. The highest yields from the Queen of the Vineyards were recorded on 161-49, followed by 1202 and 99R; from Muscat of Hamburg, on own-rooted plants, 41B and 110R; and from Dabouki, on 41B, 110R and 161-49. No correlation was, however, noted between the ranking of scion/stock combinations as to vigour and their ranking as yielders.

Bradt and Hutchinson observed an increased yield when less vigorous cultivars New York Muscat and Delaware were grafted on 1202, 5309 and 5BB rootstocks. The behaviour of 14 cultivars on 3 rootstocks was observed for 6 years. The highest yields were produced on Chasselas × Berlandieri 41B, grape sugar content in most cultivars was 1-2% higher on Rupestris du Lot or Berlandieri × Riparia Kober 5BB than on Chasselas × Berlandieri 41B. The root-stocks did not appear to have any marked effect on acidity, but Berlandieri × Riparia Kober 5BB induced more vigorous scion growth than the others. In another experiment, five table grape cultivars were compared on 3 rootstocks. On Chasselas × Berlandieri 41B and BerlandierixRiparia Kober 5BB the scion cultivars produced higher yields with a 0.6-0.9% lower sugar content than on Rupestris du Lot. The growth vigour of the different rootstock-scion combinations was similar with certain exceptions. Cardinal cropped well on ChasselasxBerlandieri 41B but produced grapes of poor colour and flavour. In trials started in 1949, nine vine cultivars were grafted on 6 rootstocks. Five gave the highest yields when grafted on Berlandieri × Riparia

420A or 5BB rootstocks and the lowest yields on Riparia × Rupestris 101-14. The sugar content of must varied considerably between cultivars and years. Several stock-scion combinations suitable for the conditions of western Georgia were suggested . Prasad reported the percentage of grafting success, growth and 3-year cropping of 6 vine cultivars on 6 rootstocks. Grafting success and yields were highest with Thompson Seedless on Perlette or Kishmish Red rootstocks. The vine cultivars Zhemchug Saba, Shasla, Belaya, Karaburnu, Riesling, Aligote and Pinot noir were grown on their own roots or were grafted onto Riparia × Rupestris 101-14 to determine the effect of the rootstock on plant productivity. in the local humid subtropical conditions of the trial, the rootstock had no detrimental effect on growth, quality or yield and even improved growth and yield in Shasla Belaya, Karaburnu and Aligote. Shoot growth in the grapevine cultivars Chasselas, Aligote and Riesling was better when these cultivars were grafted onto the rootstock Kober 5BB than onto RipariaxRupestris 101-14, but for cv. Cabernet the opposite was true. Yields were higher in Chasseias and Aligote grafted onto Kober 5BB than onto the other rootstock, but with Riesling and Cabernet the opposite was true. Grape sugar content rose with yield except in Chasseias where it was higher in plants grafted onto Riparia × Rupestris 101-14.

Mortensen in his experiment with 11 rootstocks and 11 scions, observed that Dogridge rootstock was most compatible with all the scions used in his experiment and produced the most vigorous plant. The effect of 10 rootstocks on 3 scions was studied at different sites in the Eger region. The most suitable rootstock was found to be Berlandieri × Riparia 5BB. Although the cv. Kadarka performed best on Rupestris du Lot, Italian Riesling on 5BB and White chassel as on Vinifera × Berlandieri 41B but the effect was not so superior as compared to Berlandieri × Riparia 5BB. Dimitrov *et al.* in their studies with 10 different rootstocks, recommended to use Berlandieri × Riparia Kober 5BB, Berlandieri × Riparia 504, BerlandierixRiparia, Teleki 5C or Chasselas × Berlandieri 41B for Bulgarian condition. Searanari *et al.* recorded maximum yield from Seyve Villard 5276 vines on Riparia-Rupestris-

Cordifolia 106-8 followed by those on Riparia Gloire compared to those grafted on Rupestris du Lot and Riparia × Rupestris 101-14.

Deol and Bindra reported that top working of Perlette and Thompson Seedless grapevine on Khandhari and Hussaini rootstocks increased the yield, vine vigour, bunch and berry size. The cropping was also advanced compared with these cultivars on their own roots. From 10 years of trial with 6 rootstocks cultivars for Veltlinar Grun on central European (Czechoslovakian) sites, the best harvests with regard to both quantity and quality were obtained with the rootstocks Riparia × Rupestris Selection, Bzence and with Aramon × Rupestris G.I. The lowest yields were obtained with the rootstocks Berlandieri × Riparia 8B and with Riparia portalis. From the results of investigation for 9 years on the effect of Chasselas × Berlandieri 41B, Kober 5BB and Teleki 8B rootstocks on the yield and quality, vegetative growth and economic aspects of Pearl de Csaba grapevine, Chasselas × Berlandieri 41B produced significantly higher mean yields, percentage of first class grapes and return than the other 2 rootstocks. No significant differences in sugar and total acid contents were caused by the rootstock. Attempts were made to substitute Berlandieri × Riparia Kober 5BB rootstocks for the popular wine grape cv. Refosco. Several more suitable rootstocks were found of which Riparia × Rupestris 3309 was the best. Comparative data on the growth and productivity of 6 scions on 5 rootstocks were obtained from 6 long term field trials in California vine yards. Scions on the 2 Vinifera × Rupestris rootstocks, Ganzin 1 and Couderc 1202, in vegetative growth and fruit yield, performed well or better than those on the standard Rupestris St. George rootstock. Root examinations confirmed the presence of phylloxera on the roots of the Vinifera × Rupestris hybrids.

Grapevine cv. Merlot, grown on six rootstocks and trained by the sylvoy system was studied by lannini *et al.* They observed maximum shoot vigour of Merlot when grown on Berlandieri × Rupestris 779P, followed in order by vines on Rupestris du Lot, Kober 5BB, Berlandieri × Rupestris 140 Ruggeri, Kober 420A and

Riparia × Rupestris 3309C. While berry sugar content per unit leaf area was found maximum when grown on 3309C and 420A.

Hedberg recorded maximum increase in yield of several vine cultivars when grafted on Ramsey (formerly Salt Creek) and Dogridge rootstocks. Basso and Natali observed maximum (9.11 kg/vine) yield of Sangiovese Toscanc when grown on SO4, followed by 420A and 779P while the highest sugar yield (1.883 kg/vine) was observed on 420A rootstock. The grapevine cv. Merlot grafted on Ruggeri 140, Richter 110, Craciunel 2 or Dragasani 57 yielded 17.04, 12.9, 11.4 and 10.5 t/ha, respectively. The grape scion cultivars Alman, Avrupa, Riesling were grafted on three BerlandierixRiparia rootstocks — Kober 5BB, Teleki 5BB and 8B and their graft union and rooting were studied. Buds grew in all Alman grafts on all rootstock, in >90% of Avrupa grafts on all rootstock; but growth was least (70.5%) in Riesling on Teleki 5BB. Rootstocks on rooting were noted in Alman and Riesling only.

Trials were carried out with the grapevine cv. Krakhuna grafted on the following rootstocks : Riparia × Rupestris 3309, Riparia × Rupestris 3306, Berlandieri × Riparia 420A, Riparia × Rupestris 101-14, Chasselas × Berlandieri × 41B, Berlandieri × Riparia Kober 5BB and Rupestris du Lot (control). Vines on Chasselas × Berlandieri 41B had the largest leaf surface area/ vine and gave the highest yield (99.9 centners/ha). The next best were vines on Berlandieri × Riparia Kober 5BB with 94.9 centners/ ha. Control vines yielded 85.9 centners/ha.

Sarooshi *et al.* recorded maximum yield of Muscat Gordo Blanco on rootstock 1613 while the growth of vines was found maximum on rootstock 62-66. The performance of grapevine cv. Petit Manseng clone 15 on 5 rootstocks (Massanes, SO4, 5BB, 196-17 and 3302C), with Jurancon training was observed from 1967 to 1978. There were no significant differences in yield or in wine alcohol content among the rootstocks. Grapevine cv. Gros Manseng clone 168 (CTPS 572) was grown on its own roots or grafted on four different rootstocks. Yields were best on 5BB but wine alcohol content was insufficient on this rootstock. On Riparia-Gloire, Riparia-Rupestris 101-14 and specially Riperia-Rupestris 3309C,

alcohol content was acceptable but yields were lower. Durquety *et al.* reported that over 15 years, the grapevine cv. Tannat (clone 1215) showed no differences in yields (417.5 to 458.6 g/bud) or wine alcohol content (between 11.2 and 12.9°) on 5 rootstocks (Riparia-Rupestris 101-14, Riparia-Rupestris 3309C, Berlandieri-Riparia 5BB, Riparia-Gloire and Riparia-Rupestris-Vinifera 196-17). Grapevine cv. Cabernet Franc (clone 6F CTPS 396) was grafted on Riparia-Rupestris de Massanes or 3309C (control), Berlandieri-Riparia 420A, Berlandieri-Rupestris 110R, or Riparia-Rupestris-Vinifera 4010. The density was 2960 plants/ha, with Guyot training. Observations were made from 1968-79. Yields were highest (259.96 g/bud) on Riparia-Rupestris-Vinifera 4010 but the wine alcohol content was barely sufficient. The lower the yields, the higher was the wine alcohol content. Index of vigour (based on cane length and thickness at nodes 3 and 10) increased in order 157-11, 34 EM, 101-14, 140 Ru, 41B, 420A, Golia, Kober 5BB. This index was correlated negatively but not significantly with stomatal density. Stomata occurred more densely at the leaf tip than at the base, and on leaves towards the apex of the cane than on basal leaves. Grape yield and soluble solids yield per ha for the cultivars Riesling Italico and Malvasia di Candia, and acid content and shoot vigour of all cultivars were greatest on 140 Ru. Yields of soluble solids/ha of Malvasia Istriane, Pinot Bianco and Sauvignon were better on 420A .

In a comparison of the two grape cultivars on rootstocks Rupestris du Lot, Berlandieri × Rupestris 1103/P, Berlandieri × Rupestris 775/P, Berlandieri × Riparia 161/49, and Berlandieri × Riparia 157/11 over a 4-year period, the highest yield of bunches/ plant and weight of grapes/ha were given by 775/P and 1103/P with Sangiovese and 157/11 and 775/P with Trebbiano Toscano. The mean yields of Trebbiano exceeded those of Sangiovese.

In a similar experiment in Italy on Merlot, Cabernet Sauvignon, Pinot Grigio (Pinot Gris) and Verduzzo Trevigiano in combination with 10 Berlandieri × Riparia and Rupestris rootstocks, Belvini *et al.* obtained significant differences between cultivars, rootstocks and years, and between most of their interactions, in terms of berry yield/ha, number and average weight of bunches, sugar content, acidity and weight of prunings. With all cultivars except Pinot Grigio, Berlandieri × Riparia Teleki 8B sel Cosmo 10 was among the rootstocks giving the highest berry yields, and for all cultivars Berlandieri × Riparia Teleki 5C was among those giving the lowest berry yields.

In a trial with the grape cv. Sultania (Thompson Seedless) grown on a range of different rootstocks or on its own roots, the highest average yields (27 t/ha) were obtained from vines on 143 B Mgt, compared with 18 t/ha for own-rooted vines. Resistance to the disorder GSV (growth arrestment disease) was also greatest on this rootstock.

In Barcelona, Spain, the yield recorded over 3-10 harvests in cv. Xarel Lo grafted on 41B, 11OR, 161-490 SO4, 140Ru or 1103P (1103) rootstock, was highest (1.39 kg/m^2) with SO4, and 41B (1.18 kg/m^2) was also satisfactory. The least productive rootstocks were 1103P and 161-49C but 1103P had the highest sugar content (166.3 g/litre must).

In South Africa, the effects of four bud loads (16-40 buds/vine) and six rootstock cultivars 101-14 Mgt (*V. riparia* × *V. rupestris*),99 Richter (*V. berlandieri* Var Las Sorres × *V. rupestris* var. du Lot), 110 Richter (*V. berlandieri* var. Resseguier No. 2 × *V. rupestris* var. Martin), Ramsey (var. of *V. champini*), Constantia Metallica (seedling of *V. rupestris* var. Martin), and Rupestris du Lot (*V. rupestris* var. du Lot) were investigated by Archer and Fouche. Parameters including yield, cane cluster and berry weight, budding percentage, bud fertility, leaf surface area, grape composition and wine quality were measured. Both bud load and rootstock had significant effects on all parameters and the effect of bud load depended on rootstock. Considering all parameters 110 Richter and Ramsey gave the best results.

The effects of rootstocks (Schwarzmann, Ramsey, Dogridge, Harmony, Freedom, K15-40, K51-32, 110R, 140R, 101-14, 1202, 1616, 1613, ARGI, 420A SO4, 5BB, 5A and Rupestris du Lot) on the pH and mineral and organic acid concentrations in grape berry juice of the scion cultivars Riesling, Ruby Cabernet, Shiraz and Chardonnay were investigated by Ruhl *et al.* at Loxton (South Australia), Nuriootpa (South Australia) and Rutherglen (Victoria). Ungrafted vines of Riesling, Ruby Cabernet and Shiraz had low to medium juice pH (3.03, 3.43 and 3.56, respectively) while ungrafted vines of Chardonnay had high juice pH (3.74 and 4.01 at two different sites). Harmony, Dogridge, Freedom and Rupestris du Lot rootstocks generally caused a high juice pH, whereas 140R, 1202, 5A, SO_4 and 101-14 rootstocks gave a low juice pH. Positive correlations were found between juice pH and juice potassiuam, malate and, in some cases, sodium concentrations. Tartrate concentration and the tartrate/malate ratio of juice and sometimes juice chloride concentration were negatively correlated with juice pH. The rootstocks' effects on juice pH could be attributed to changes in potassium and sodium concentrations or in the tartrate/malate ratio.

Observations made during the first 5 years from grafting have been reported by Aimone and Bovio. Rootstocks 125AA and Kober 5BB caused rapid vine development and early grape production. Vines on 1103P and Rupestris du Lot demonstrated a good balance between vegetative growth (not excessive), yield and grape quality, 140 Ru gave less satisfactory results and 3309C was unsuitable for the cultivar Barbera.

Two rootstocks and 3 N fertilizer rates were evaluated for their effects on growth, yield and petiole nutrient concentrations by Wolk and Pool. The rootstocks, Couderc 3309 (C-3309) and Elvira had a greater effect on scion growth than did the N application rates — 10, 30 or 84 kg/ha annually, even though increased avilability significantly increased N content in the 2nd year of application. Grafting on C-3309 produced larger vines but this did not result in proportionately greater fruit yields. The percentage of flowers that set fully developed berries tended to be higher for vines on Elvira than on C-3309 rootstocks. Fruit set on vines on C-3309 receiving no N was greater than on vines that received 84 kg N/ha. Vines on C-3309 rootstocks were also associated with greater shoot growth rate, higher petiole K concentrations and denser canopies, compared with vines on Elvira.

The suitability of 6 rootstocks and 6 training systems for clone 61/5 were examined. ChasselasxBerlanderi 41B was the best rootstock in spite of giving a 11.85% lower production of grafted cuttings than the other rootstocks. Vines on 41B produced a 12.0% higher grape yield than vines on the other rootstocks. Training by the Lenz Moser or Roaja system produced 30.50% higher yields than other systems. For vineyards on stony ground, Rugero-140 rootstocks were recommended by Gjermani.

In a 3-year study on the effects of 10 rootstocks on the performance of cv. Croatina vines and on leaf contents of N, P, K, Ca and Mg, fruit yield, bunch weight bud fertility and berry sugar content and titratable acidity, Volpe and Bosselli reported that rootstocks appeared to influence mineral nutrition more than yield parameters. Rootstocks of the *Vitis riparia* X *V. rupestris* group (notably 3309) showed the best affinity with Croatina and fruit quality was best in vines grown on these rootstocks.

Li *et al.* grafted two-year-old Fujiminori vines onto 7 rootstocks, 3309, 3306, 101-14, 5C, 8B, SO_4 and 420A and observed that growth was more vigorous on 3306, SO_4 and 101-14 than on other rootstocks. The number of flower cluster/shoot was greatest with 420A, 8B and 3306 and least with 101-14. There was no differences in the number of flowers/cluster between rootstocks but the rate of panicle elongation was faster on 101-14 and 5C than on SO_4 and 420A. The percentage of fruit set was highest in vines on 420A, with no difference between other rootstocks. The largest berries occurred on 3306 followed by 101-14 and 3309. The highest TSS occurred in fruits from vines on 3309, SO_4 and 3306 rootstocks. The titratable acid content was relatively low in fruits from vines on all rootstocks, particularly those on SO_4.

Nikolenko and Andryukhin reported that cv. Agadai yielded better on Kober 5 BB rootstock while cv. Muscat of Hamburg did so on 41B in Ukraine.

In Australia, Sultana (Thompson Seedless) vines on Ramsey rootstocks produced higher annual yields than own-rooted vines and vines on Dogridge rootstocks (24.0 vs. 20.8 and 17.8 kg/vine, respectively), produced more canes/vine but fewer bunches/node than own-rooted vines.

Effect of Rootstock on Mineral Composition

Yield data, pruning weights and petiole samples were obtained annually in a 6-year study of a vine rootstock-scion trial in Napa Valley, California. The trial involved 22 scion cultivars and 3 rootstock, St. George, AxR No. 1 and 99-R. At flowering time petioles were analysed for NO_3, K, P, Mg and Ca contents. Fruit yields, pruning weights and petiole composition were compared by scion cultivars and by rootstocks. A wide range was found among the scion cultivars in all comparisons. The stock AxR No. 1 induced the highest fruit yields and intermediate nitrate levels, St. George induced the highest vegetative growth, and the weakest stock, 99-R was the most efficient in terms of fruit yield per unit of growth. The St. George stock generally produced the highest petiole nutrient the scions. In years favourable to high nitrate levels in formation, St. George caused excessively, high petiole nitrate levels and these levels were shown to be inversely correlated with fruit production. The rootstock significantly affected the leaf contents of N, P, Ca and Mg. The highest N contents occurred in plants grafted on Rupestris du Lot, IAC 313 (tropical) and Golia. Phosphorus content was highest with Rupestris du Lot and Golia. Berlandieri 021× Riparia (420A) produced the lowest K content. Calcium content was highest with IAC 313 (tropical) and Bourrisquou × Rupestris 93-5 (Couderc) and Mg content was highest in Seibel 2 on its own roots. Trials conducted at the Roussillon region with grapvine cv. Grenache on 4 Berlandieri Rupestris hybrid rootstocks (Richter 110, Richter 99, Ruggeri 140 and 1103 Paulsen) showed that plants on R 99 contained less amount of phosphorus but more potassium in leaves than others, while plants on R 110 and 1103P contained more amount of leaf Ca than the other two roostocks and plants on R 140 contained less Mg than others.

An investigation on NPK nutrition due to the interaction of scion and stock was carried out by grafting several cultivars (mostly *Vitis vinifera* and some hybrids) on themselves, on each other or on rootstocks, or grown on their own roots. Isografts generally showed higher contents of N, P and K (especially P) than the same cultivars on their own roots, especially for *V. vinifera*.

In heterografts, scion/rootstock interactions were marked. Cv. Victoria, with a large biomass, had a high N requirement whereas Petit Sauvignon 62 had high P and K requirements. Used as rootstocks they led to better N absorption and weaker P and K absorption than when grown on their own roots. The rootstock Ruggeri 140, grown on its own roots, had lower N, P and K requirements than *V. vinifera* cultivars, when it was grown as a rootstock N and K absorption were increased and P absorption reduced.

The K, Ca and Mg contents in petioles of 4 cultivars (Cabernet Sauvignon, Merlot, Sauvignon and Ugni blanc) grafted on 70 rootstocks were used by Ponget in the equilateral triangle system to distinguish rootstocks by their ability to absorb these elements. The method was also used to identify rootstocks resistant to Mg deficiency.

Fardossi *et al.* stated that cv. Neuburger on Euro-American hybrid rootstocks 26 G and 333 EM contained lowest K but the highest Ca concentration in leaf blades.

Incompatibility

Some clones of cv. Abouriou were incompatible with the rootstock 5BB and grafted plants showed red foliage within 2 years followed by death in the 3rd or 4th year. Other clones were compatible. In trials which included other clonal rootstocks, Abouriou 'Vert' was compatible with all of them and Abouriou, 'Rouge' continued to be only incompatible with 5BB. With cv. Cabernet Sauvignon, clones 11.06 and 11.15 were compatible with rootstock cv. SO_4 and incompatible with 5BB, whereas clones 11.11 and 11.12 were compatible with 5BB and incompatible with SO_4. One clone, 11.01 was compatible with both rootstocks.

MICROPROPAGATION

Fuji and Nito obtained callus from cambium of grape internode on an agar medium containing inorganic nutrients, vitamins, 1 ppm NAA and 1 ppm kinetin. After 2-3 weeks the calluses were transferred to a similar medium containing 2 ppm NAA and 10 per cent coconut milk, they were then subcultured on this medium

every 3 weeks. The extent of subsequent fusion between calluses depended on taxonomic closeness of the 2 partners.

Callus tissue formed adventitious embryos when transferred from a medium with 2, 4-D to a medium containing NAA. Embryos began to turn green and develop into apparently normal plants when placed on a medium free of hormones and vitamins in the light. Histological evidence indicated that plants derived from callus originated from embryo like structures and not from plantlets or excised buds. Favre tested the various plant parts and the leaf blades proved to be the best material for raising new plantlets that could be of use for clonal propagation. The most successful medium for inducing spontaneous callus formation and organogenesis contained Murashige and Skoog's and Heller's nutrients, Morel's vitamin solution, FeEDTA and 10^{-6} M IAA. Healthy growth of serially subcultured callus of the grape cv. Sylvaner Riesling was obtained by incubation at 30°C in continuous light in a defined culture medium containing 2 per cent sucrose, 1.0 mg/l IAA and 0.2 mg/l NAA and 0.2 mg/l kinetin. Organogenesis was not induced in this callus by alteration in the absolute or relative levels of NAA and kinetin. Continued shoot initiation was obtained by culture of axillary buds in a medium containing 10—5 M benzyladenine. Plantlets could be generated from these shoot buds by transfer to media containing 10^{-7} M benzyladenine.

Bernard and Mur obtained plantlets of grape cv. Ugni Blane *in vitro* from internodal cuttings, each 2-3 cm long with an axilary bud at the top.

Barlass and Skene examined the hormonal and nutritional requirements for the culture of fragmented shoot appices of grapevine, benzyladenine at 10 µM added to full-stregth Murashige and Skoog basal medium was found to be optimal for the growth of leaves and shoots. Tissue and organ differentiation was obtained when meristem of cv. Sultana was cultured in a Murashige-Skoog-Nitsch medium containing 1mg/1 IAA and 2 mg/1 BA. Callusing was induced by withholding BA, replacing IAA with NAA and adding 1 mg/1 GA_3. This callus, however, could not produce shoots after transfer to a new medium containing both IAA and BA. For rooting in shoots from meristem culture, a medium containing 1 mg/IAA, 0.2 mg/1 BA and 10 mg/1 cysteine HCl was found to be the most suitable. Apical fragments of 12 grapevine cultivars were grown in Murashige and Skoog (MS) liquid medium supplemented with 2 mg/litre BA. Differentiated fragment transferred to the same medium solidified with agar produced shoot masses which could be repeatedly subcultured. Excised shoots readily initiated roots on hormone-free white's medium or half-strength MS medium supplemented with 0.1 mg/litre NAA (depending on the cultivar). Plantlets were successfully potted and subsequently planted in the field. Silvestroni observed the highest rate of proliferation (8-10 shorts per cutting) with a high level of BA (2 mg/1), but the internodes were short. Fewer (4-6) but longer shoots were found with less BA (0.5 mg/1) and rooting was readily achieved in a BA-free medium.

The growth characteristics of medullary and cambial explants from the grapevine rootstocks K-l, SO4, 125 AA and ARIP, and from the scion cv. Neuburgske grafted on them, were studied in tissue culture. Both the medullary and cambial tissues of the scion cultivar showed greater growth activity than those of the rootstocks. Shoots developed from 0.5-1.0 mm long apices (containing 24 leaf primordia) of the grapevine cv. Rougeon with 5×10^{-6} M BA plus 5×10^{-7} M NAA under a 10-hour photoperiod on Murashige and Skoog media. Shoot production in the hybrid cv. Baco grown on Murashige's minimal organic medium (MMO) supplemented with 80 mg/1 adenine sulphate, 170 mg/1 sodium phosphate (monobasic) and 3-4 mg/1 BA, was increased 7-fold by starting on media solidified with 0.7 g agar/1 for 4 weeks and then reculturing to liquid media. Over 90% of the shoots rooted readily in 7-14 days when supported on filter paper bridges in quarter-strength MMO liquid supplemented with 150 mg/1 sodium phosphate, 10 g/1 sucrose and 0.1 mg/1 IAA. Leaf and leaf-stalk tissues of the grapevine cultivar Cardinal were cultured on modified Murashige and Skoog medium with or without ID-82 (an auxin derivative). Good rhizogenesis was obtained in vines with ID-82 at 4.0x10-0M.

With basal Murashige and Skoog (MS) medium, the effects of cytokinins were tested on the growth and development of isolated meristem tips of 8 grapevine rootstock clones. Axillary bud formation was induced and cultures of continually proliferating shoots of all clones were obtained on this medium supplemented with 10 µM BA. Half-strength MS medium with the addition of 0.1 µM IBA was effective for root formation in most clones.

Many embryos and plantlets were produced from callus of somatic origin formed by cultured anthers of several *Vitis* species and hybrids and by an Australian *Cissus* sp. Grenache was the only *V. vinifera* cultivar to produce embryos. The ability of anthers to form callus and embryos varied with genotype. Anthers from male plants produced more calli and embryos than anthers from female or hermaphrodite plants. Feminization of male inflorescences by the use of cytokinins resulted in the loss of ability of anthers to form callus *in vitro*.

Adventitious shoots were induced on apical fragments of cv. Meunier, a presumptive periclinal chimaera which resembled Pinot noir in essential characteristics but was distinguishable by the dense white mat of hairs on the apex and expanding leaves (tomentose phenotype). The results indicated that adventitious buds of grapevine produced by this method were multicellular in orgin and were not derived from single cell. Furthermore, it was concluded that in fragmented shoot apex culture of grapevine periclinal chimaeras disturbed the integrity of apical tissue and was not recommended where true-to-type propagation was required.

Twenty-one genotypes comprising *Vitis* spp., *V. vinifera* cultivars and interspecific hybrids were propagated *in vitro*. Survival for 55 days after culturing was total in 7 genotypes and 80 per cent in 13 and it was poor in the hybrid Seyval. Shoot production was observed in all the genotypes, reaching 50 per cent or over in 18 of them and 75 per cent in 14. Only in *Vitis argentifolia*, a 16-hour day length was more successful in inducing shoot formation than a 10-hour day length. Shoot multiplication was best in the hybrid Remaily Seedless and worst in *Vitis labrusca* cv. Catawba which died. Rooting occurred in all the 15 genotypes tested, but was poor in 4 of them, good rooting was generally associated with vigorous shoot formation.

Grenan and Caraux cultured cuttings of 5 cultivars *in vitro* at 20°C or heat treated at 38°C for 70 days or at 38°C for 70 days followed by a further 90 days at 30°C. Plant from the heat-treated cuttings were free from viral infection but showed altered leaf morphology. The modification was stable in vineyard condition, but the vegetative progeny from the treated material showed a morphogenetic gradient along the branches.

The hybrid Remaily Seedless was cultured using shoot explants with 3-4 nodes and a medium based on Murashige and Skoog. Adenine sulphate at concentration in the range of 2.5-20×10^{-4}M depressed shoot multiplication with the optimum concentration of BA which was 5 µM.

In cultivars Sangiovese and Trebbiano, Morini *et al.* reported better shoot tip growth and proliferation on Murashige and Skoog medium than on WPM (woody plant medium) or PM. In further trials with the cultivars Caniolo Nero, Malvasia Bianca and Malvasia Nera, the first two proliferated better than the last, while the rootstock cv. Kober 5BB showed a higher proliferation rate than 420A, 140 Ruggeri or 1103 Paulsen. It was not found whether these varietal differences were due to differences in the incidence of vitrification (possibly related to excessive humidity). The shoots generally rooted and subsequently acclimatized well.

Seedless cv. A Dona meristem tips were grown on Nitsch and Nitsch medium with BA at 1.0, 2.0, 5.0 or 10.0 µM. Concentrations of 2.0 and 5.0 µM gave the best growth.

Shoot proliferation from 1 to 2 mm long apices cultured on modified MS medium containing 5 µM BA was reported by Gray and Fisher using *Vitis aestivalis*, *V. bourguniana*, *V. champini* cv. Dogridge, Longii, *V. munsoniana*, *V. rupestris*, *V. rotundifolia* (cultivars AD 3-42, Carlos and Dixic), *V. shuttleworthii*, *V. tiliafolia* and *V. vinifera* (cultivars Carignane, Chenin Blanc, Flame Seedless, French Colombard, Italia Alabastrina, Lambrusco and Tokay). Proliferation was increased by careful dissection (to avoid subtending stem tissue) and selection of apices. The addition of NAA to the medium did not enhance shoot proliferation.

In some cultivars, Fanizza found that culture of shoot tips at 32°C with 0.8 mg BAP stimulated root formation; in others, it did not.

Nodal segments of *Vitis labrusca* cv. Delawre, *V. thunbergii* and *V. vinifera* cv. Rizamat were cultured by Moriguchi and Yamaki in MS medium in which ammonium nitrate concentrations were 6, 25 or 100% of full strength (1650 mg/litre). Storage at low ammonium nitrate concentrations (6 or 25%) instead of low temperatures gave survival rates of 70-80%. Shoot production was also greater when nodal cultures were stored at low ammonium nitrate concentrations rather than at low temperatures.

Cheng and Reisch cultured apex tissues from axillary buds on MS media supplemented with 4 µM benzyladenine (BA). Up to 15% of leaf and 70% of petiole explants, derived form the *in vitro* cultured shoots, regenerated shoots on media with 5-10 µM BA and 0.1-0.5 µM IBA. Incubation in the dark was required for regeneration and cultures grown in the dark for 2, 4 and 8 weeks produced shoots from 2.5, 15 and 20% of explants, respectively. Regeneration from petioles and leaves was always from the basipetal end.

Shoots from apical meristem cultures were repeatedly subcultured by Hart1 and Jelaska on basal MS medium containing 8.9 µM BA. Shoot proliferation occurred on this medium as a result of axillary bud induction. Deformed shoots developed on media with higher BA concentrations. Plants produced *in vitro* were of juvenile type with no tendrils and with spiral phyllotaxy.

Proliferation of *Vitis vinifera* cv. Liemberger shoot tip explants in a liquid medium was compared in 125 and 250 ml Erlenmeyer flasks and in 473 ml Mason jars. After 6 weeks of culture, the jars yielded a significantly greater number of shoots, 3 mm or longer than did the flasks. Jars yielded the greatest number of shoots, 7 mm or longer, followed by 210 ml, then 125 ml flasks.

A significant increase in the number and relative volume of some cell organelles occurred in the cv. Cardinal treated with F-2 (containing cytokinin, auxin, gibberellin and ABA) at 10^{-2} M some 5 days before bud burst.

Dalal *et al.* used terminal shoot tip explants taken from field grown mature plants of cvs. Pusa Seedless and Beauty Seedless for studying the seasonal variation in phenol level of shoot tips and its relation with explant survival. A curvilinear regression model of second degree polynomial was fitted to the trend of variation of explant survival *in vitro* and pre-existing total phenols in relation time of explant isolation. In general, *in vitro* survival was achieved from explants taken in March and September, with the lowest survival rate from those obtained in June. Lower phenolic levels was found associated with higher explant survival.

Li and Eaton studied the growth and rooting in shoot apices from cultivars Cascade and Marechal Foch soaked for 15 minutes in 0, 1.33×10^{-3}, 2.22×10^{-3} or 3.34×10^{-3}M BA and then transferred to a solid medium containing 0, 2.9×10^{-6} or 5.7×10^{-6}M NAA. Greatest shoot weights were achieved with combinations of high level of BA and NAA. The shoots obtained were soaked for 15 minutes in 0, 1.48×10^{-3}, 2.46×10^{-3} or 3.94×10^{-3}M IBA and then placed in water or half-strenght or full-strength solid Murashige and Skoog medium. The average number of roots/explant was highest in Cascade shoots pre-treated with 2.46×10^{-3}M IBA and cultured on half-strength medium (4.6 roots/explant) and in Marechal Foch shoots pre-treated with 3.94×10^{-3} M IBA and cultured on full-strength medium (4.0 roots/explant).

Baditescu *et al.* reported regeneration of 40 plantlets from a single growing point in a course 6-7 weeks.

Seven new disease resistant cultivars and 2 susceptible control cultivars were cultured on 3 media (2 liquid and 1 solid) under different conditions to determine the best method of propagation. The methods recommended by Golodriga involve culturing buds on liquid medium with BA to increase the number of buds available, rooting the buds obtained on solid or liquid medium, conservation of the plantlets obtained under artificial conditions, if necessary and adaptation of plants to nonsterile greenhouse conditions between March and June.

Callus induction frequencies on an agar medium containing Murashige and Skoog salts+BA (2 mg/litre)+2, 4-D (0.5 mg/litre)+kinetin (1.0 mg/litre)+sucrose (3%)+LH (500 mg/litre) were reported by Wang *et al.* Mean induction frequencies for 5 cultivars were 73.47% for tendrils, 56.26% for internodes, 46.63% for stem tissue and 12.14% for fruit stalks. The mean induction frequency for these 4 tissues was highest, 85.38% in the cv. Bai Xing Jiaol and lowest, 33.9% in Ju Feng.

Primary callus derived from leaves and young stems was subcultured for 4 months, then maintained at 4°C for 3 weeks in a medium without growth regulators. In material derived from Cabernet Sauvignon, Antey and Podarok Magaracha, shoot regeneration was obtained in a MS medium modified by the addition of various sugars, ascorbic acid, BAP, GA_3. A MS medium with added IBA and activated charcoal induced root regeneration. Whole plantlets were transferred successfully into soil.

Explants from buds, shoots and other parts of the cultivars Pamid Cheren, Pamid Cherven and Rusalka were cultured on 9 different nutrient media. For direct organogenesis the best results were obtained on MS medium at half-strength and on Gamborg medium. For rooting the plantlets, Balkanme and Zeolite substrates (unspecified) were the most suitable.

An *in vitro* propagation programme of commercially important cultivars Marechal Foch, Precose del Colmar and Siegfried was taken up by Hicks and Dorey. Terminal and axillary buds from growing vines were used to establish stock multiple shoot cultures on medium supplemented with BA. In shoot multiplication trials, the highest shoot numbers were observed after 12 weeks using 5.0 µM BA; shoot morphology was somewhat distorted at 5.0-10.0 M, but not at lower concentrations (2.5-3.75 µM). In rooting trials, rapid rooting at high frequencies was observed on MS medium. IBA increased the number of roots in some trials, and rooted microcuttings were grown successfully in soil.

Lee and Wetzstein reported recovery of plantlets from axillary bud cultures of cv. Summit. Nodal segments 0.5 to 1.0 cm long were cultured in MS basal medium supplemented with 5, 10, 20 or 40 µM BA. The best total shoot production was obtained with 10 µM BA, with higher BA levels shoots were unexpanded and exhibited high mortalities. MS medium supplemented with IBA enhanced rooting by increasing rooting percentage and root number per plantlet. Shoots previously proliferated on medium with 5 μM BA rooted significantly better than those on 10 μM BA. Shoot vigour during rooting was greater in shoots proliferated on 5 vs. 10 μM BA. Root development was not significantly affected by liquid vs. agar-solidified medium or shoot length.

Radojevic recorded that plants could be produced economically by secondary embryogenesis (i.e. from embryoids) from the cv. Seyval only, as little is known about the induction of embryogenic calluses in other cultivars. Vegetative propagation using apical shoot tips with heat treatment is considered the most suitable and practical method of virus-free plant production.

The results obtained by Bini and Capuana with micropropagation were variable, depending on the plant material used (vegetative apices, meristems, buds and nodes), the period when the material is taken, the type of substrate, light and temperature conditions and species and cultivar.

Yu and Meredith reported a strong negative correlation (r = 0.87) between explant survival and total phenol content of the shoot tip. Phenol content was influenced by position, light and vigour, these factors beings of differing importance in different cultivars.

Anther Culture

Somatic embryogenesis and plant regeneration from anther was reported by Mauro *et al.*. Callus derived from the somatic tissues of the anther was subcultured on medium containing casein hydrolysate and subsequently produced embryoids. This process was stimulated by the addition of glutamine and adenine to the medium. The early removal of cotyledons from the embryoids increased the frequency at which they developed into plantlets. There was significant variation in ability to produce callus and embryoids among the 3 clones studied.

Ovule and Embryo Culture

Ovules of seeded and seedless cultivars were excised on successive dates between 0 and 101 days after anthesis and

cultured on 10 media. Ovules excised between anthesis and 14 days after anthesis grew abnormally. Ovules excised at 24 and 31 days developed into seeds with a normal external appearance but contained no embryo or endosperm. Vaible embryos were found in ovules excised after 38 days.

The ovules from open pollinated fruits of 10 seedless grape clones and cv. Concord were cultured for 8 weeks after the embryos were excised and subcultured. Embryo survival per 120 ovules cultured ranged from 0 to 110 depending on the clone.

Embryos of grape cv. Baishangiiao, taken 15 days after flowering, failed to produce plantlets when cultured on modified B5 medium, whereas embryos taken at 30 days produced green plantlets. After transplanting, these plantlets grew normally. Treatment at 5±2°C for 46 days increased the percentage of plantlet regeneration (27.7%) compared with control (11.1%).

Zygotic embryos isolated from mature berries of *Vitis longii* and the *V. vinifera* cultivars Chardonnay, French Colombard, Grenache and White Riesling produced somatic embryos when cultured on solid Nitsch and Nitsch medium. Explants of Pinot noir did not produce somatic embryos. The highest incidence of somatic embryogenesis occurred on medium containing 1.0 mg NOA+0.2 mg BAP/litre, except in white Riesling, where 1.0 mg NOA+1.0 mg BAP was optimal. Somatic embryos developed asynchronously from a mass of white proembryos and passed through globular, heart and torpedo shaped stages. Embryos proliferated by budding at the surface of globular embryos.

Ovules of 14 seedless cultivars, collected 41-49 days after anthesis were excised and cultured *in vitro* on 2 different media; NN+μMGA_3+10 μM IAA and NN+μM GA_3+20 μM IAA+2g/l activated charcoal. Plantlet development was found to occur at variable rates, the best percentage were found in Flame Seedless, Carina, Perlette and Ruby Seedless. It was thought that genotype was the main factor affecting ovule response to culture, but the medium and genotype × medium interaction also influenced it.

Protoplast Culture

Suitable condition for induction of protoplast division *in vitro* were studied. Of the growth regulator combinations tested BA at

1 mg/litre with either 2, 4-D at 1.5 mg/litre or NAA at 3 mg/litre gave the best results. Most protoplasts regenerated cell walls after 2 or 3 days of culture. The first cell divisions occurred within 10-12 days, and under certain conditions mitotic activity continued with some cells dividing 2 or 3 times.

Experimental conditions were developed that resulted in high yields and viability of the protoplasts obtained from leaves regenerated *in vitro* by somatic embryogenesis. Highest protoplast yields (up to 40×10^6 protoplasts/g leaf tissue) were obtained by incubation for 2-3 hr in a solution containing 1% cellulase onozuka R10, 0.5% Macerozyme R10 and 0.7 M mannitol. Most protoplasts obtained in this way regenerated cell walls within the first few days and cell division occurred after 10 days of culture in a liquid medium. Some cells divided 2 or 3 times but did not continue to divide beyond this stage.

Microcutting

Grapevine microcuttings grown *in vitro* were subjected to different culture conditions and three factors were studied: genotype, sucrose content of the medium and physical conditions of culture. These factors influenced the growth of plants, uptake of carbohydrates from the medium and uptake of essential minerals. The overall actions of each of the 3 controlled factors were significant in most cases. At 21°C genotype and culture conditions influenced length, FW and DW of the plants and the amounts of carbohydrates and nitrate taken up, however, the relative DM content of plants remained normal.

In Argentina, microcuttings (3-4 nodes) taken from plantlets cultured *in vitro* in MS medium containing BA at 1mg/litre, GA at 0.5 mg/litre and sucrose at 30 mg/litre were transferred to the same medium supplemented with NAA at 0.01 mg/litre. After 30 days, rooted cuttings were subcultured on growth regulator-free medium where they formed 8-10 node shoots. Single-node microcuttings from these shoots were subcultured on half-strength MS medium or Gaizy medium under long day (16 hr) conditions and a day/night temperature regime of 25/20°C. On Gaizy medium, when the axillary leaf was present, the buds formed

inflorescences without formation of a stem. The flower developed normally and a single small berry containing one seed was formed on the bunch. No flowering occurred with cuttings maintained on half-strength MS medium.

Growth Variation

Changes in leaf morphology as a result of heat treatment *in vitro* was recorded by Valat. Depending on the cultivar, there is often in addition a reduction in fertility, or the plants may become sterile. There is nearly always a loss in yield. These phenomena are especially important with table cultivars such as Cardinal R., Chasselas B and Dabouki B, wine cultivars such as Chardonnay B., Cinsaut N., Gamay N., Muscat B and Pinot N.

The hypothesis that the growth of *in vitro* propagated, non-rooted shoots directly after transfer from culture is limited by photosynthetic C supply and that growth would be stimulated by CO_2 enrichment (CDE) was tested by Lasko *et al.*. Plantlets of the interspecific hybrid Remaily Seedless were grown for 30 days in air with 350 or 120 ppm (v/v) CO_2 in humidified, flow-through chambers at 26°C. Destructive growth analyses were made at 0, 10, 20 and 30 days after transfer from culture to soil. CDE had no significant effect on total plant dry weight increase in the first 10 days. By 20 and 30 days, CDE-treated plants were 2 and 4 times greater in dry weight, respectively, than the controls. Root growth was most improved by CDE, being almost 6 times greater than the controls by 30 days. Leaf area per plant and root : shoot ratio were both doubled by CDE at 20 and 30 days. It is suggested that since these results were under non-stress conditions, the use of CDE for growth stimulation needs to be evaluated under stress-hardening regimes.

Vines of the clone 7 IVS-CV micropropagated *in vitro* in 1982 and grown on in the field, differed from vines of the same clone grown from cuttings in shoot apex colour, leaf shape, leaf pubescence, bunch shape, bunch size and bud fertility. By 1985-86, the differences, notably those in leaf shape and bud fertility were less marked but there were still differences in pubescence and bud colour. Berry yields in 1986 were 9.5 and 15.1 kg/plant from the *in vitro* and traditionally-raised plants, respectively, the lower yields of the former being attributable to lower bud fertility and smaller bunch size.

Gray and Benton established regenerative axillary bud cultures from shoot apical meristem of vineyard-grown vines. Culture survival rate for cv. Fry was found highest with meristems taken from 10 cm long shoots. Shoot proliferation rate on full strength MS medium was as good as or better than on half-strength MS medium or woody plant medium. Shoot number and quality of cvs. Fry, Carlos and Dixie were highest when the medium was supplemented with 5-20 µM BA. Supplementation with thidiazuron resulted in stunted shoots. Shoots were excised and rooted in potting mix in the greenhouse with a success rate of 46 per cent.

Abracheva and Dimitrova cultured explants of various size of the grape cvs. Bolgar, Pamid, Ugni Blanc, Chardonnay, Cabernet Sauvignon, SO4 and Rupestris du Lot on MS medium. In Bolgar, Pamid and the rootstock SO4, small explants gave the largest number of developed leaves, but in other varieties large explants gave the largest number. Differences in the response to explant size between cultivars were seen also in other respects, but the marked overall tendencey was for large explants to give regenerations with the highest vigour.